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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE

WASHINGTON MEETING

AT THE

NATIONAL BUREAU OF STANDARDS

AND THE

NATIONAL ACADEMY OF SCIENCES

May 1–3, 1941

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The American Physical Society

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APRIL 17, 1941 Vol. 16, No. 2

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

WASHINGTON MEETING, MAY 1–3, 1941

THE 241st regular meeting of the American Physical Society will be held at Washington, D. C., on Thursday, Friday and Saturday, May 1, 2 and 3, 1941. The Thursday and Friday sessions will be held at the National Bureau of Standards and the Saturday sessions at the National Academy of Sciences. The first sessions will commence at 9:30 o'clock on Thursday morning.

There will be sessions in the East Building, the Chemistry Building, and the Industrial Building of the National Bureau of Standards, and in the Auditorium and Lecture Hall of the National Academy of Sciences. The schedule of papers is given below.

Hotels. The Wardman Park Hotel offers single rooms at $3 and double rooms at $5. The Shoreham Hotel (2500 Calvert Street, one block south of the Wardman Park) offers to accommodate 40 to 50 members at $5 for single and $10 for double rooms. Any member who has not yet made his reservation is urgently advised to attend to the matter at once, the congestion being great in Washington; and members are reminded that it is the policy of hotels not to hold reservations into the evening hours unless specifically so requested (with indication of the presumptive hour of arrival of the guest).

Luncheon. On Thursday and Friday the cafeteria in the Industrial Building at the National Bureau of Standards may be used at 12:30 P.M. for luncheon. As to Saturday, it has proved impracticable to make specific arrangements, and members must be left to their own devices.

Dinner. On Friday evening at 7:00 o'clock there will be a dinner for members and their guests at the Wardman Park Hotel. The price of the dinner will be $2.00 per plate including tip. Tickets must be purchased at the registration desk at the National Bureau of Standards by noon on Friday.

A Symposium on Nuclear Energy Sources in Stars will be held on Saturday afternoon in the Auditorium of the National Academy of Sciences, under the sponsorship of Professor G. Gamow of George Washington University. Professor Gamow will open and close it, and the other speakers will be Professors H. A. Bethe, E. Teller, R. E. Marshak, and C. L. Critchfield. The titles of the papers will be found on page 40 of this Bulletin.

National Research Council Conference on Electrical Insulation: Subcommittee on Physics. Dr. H. H. Race (General Electric Company, Schenectady, New York) informs us that this subcommittee will hold an informal dinner at the Wardman Park Hotel on Thursday, May 1, at 6:30 P.M.; and that after the dinner there will be a symposium on "Electric Measurements as Tools in Biological Research" with the following invited speakers:

1. DR. J. L. ONCLEY, **Electrical Characteristics of Protein Solutions.**
2. DR. KENNETH S. COLE, **Electrical Characteristics of Cell Membranes.**
3. DR. D. W. BRONK, **Electrical Aspects of Biological Functions.**

There will be plenty of time for informal discussion.

All physicists interested in this subject are cordially invited to attend. Reservations should be made before April 25 to Dr. Race.

APR 18 1941

The American Mathematical Society, which is meeting during these days at George Washington University, will hold a *symposium on the Rayleigh-Ritz method* on Saturday afternoon beginning at 2 o'clock. The following papers are to be given:

Variational Methods for the Solution of Boundary-Value Problems. PROFESSOR RICHARD COURANT, *New York University.*

Implications of the Rayleigh-Ritz Method in the Theory of the Structure of Matter. PROFESSOR H. M. JAMES, *Purdue University.*

Engineering Applications of the Rayleigh-Ritz Method. PROFESSOR J. P. DEN HARTOG, *Harvard University.*

The Council will meet at 2 P.M. on Thursday, in Room 300, South Building, Bureau of Standards.

Sigma Pi Sigma. The executive secretary of Sigma Pi Sigma (Professor Marsh W. White, State College, Pennsylvania) informs us that the customary luncheon of this organization for members and guests will be at the Tilden Gardens Hotel, Connecticut Avenue and Tilden Street, at 12:15 on Friday, May 2. Those desiring to attend should purchase tickets at one of the registration desks. The price per plate will be seventy-five cents. The Tilden Gardens Hotel is just at the entrance to the National Bureau of Standards, on the side toward the center of the city.

Ladies' Programme. The Local Committee has made plans of several excursions, the details of which are as follows:

THURSDAY

2:00 P.M. Guided tour through the new National Gallery of Art. Ladies should assemble at the Mercury Fountain in the Gallery. Luncheon may be obtained previously at the Cafeteria in the Gallery Building. Incidentally the hours during which the Gallery is open are 10 to 5 on week days, 2 to 5 on Sunday.

FRIDAY

9:30 A.M. There is a choice among the following excursions, cars for each of which will leave from the National Bureau of Standards; guests should assemble at the registration desk.

1. Visits to historic houses, including the Octagon and Dumbarton Houses, and a tour of Lafayette Square.
2. Federal Bureau of Investigation (Special tour).
3. Lee House, Arlington Cemetery, Washington Monument, and the Indian Trading Post in the Department of Interior if time permits.

Cars will go directly to Brook Farm Tea House.

1:00 P.M. Luncheon at Brook Farm Tea House, 6501 Brookville Road, Chevy Chase, Maryland. Price 85¢ including tip. Tickets for the luncheon must be purchased at the Registration Desk, National Bureau of Standards, befroe 10 o'clock Friday morning. After lunch cars will return to the National Bureau of Standards.

Mimeographed copies of the final programme will be obtainable at the Registration Desk, National Bureau of Standards. Those expecting to participate in the planned excursions are requested to sign up as early as possible on the blanks which will be attached thereto.

Summer Meeting at Pasadena. The summer meeting on the Pacific Coast will be held at the California Institute of Technology, Pasadena, California, on Wednesday, Thursday and Friday, June 18, 19 and 20, 1941, in affiliation with the Pacific Division of the American Association for the Advancement of Science.

Summer Meeting at Providence. The summer meeting in the east will be held at Brown University, Providence, Rhode Island, on Friday and Saturday, June 20 and 21, 1941. A symposium on the philosophy of physics has been arranged, and there will be opportunity for contributed papers. A dinner is to be held on Friday evening.

GENERAL RULES RELATING TO PAPERS

By vote of the Society on December 27, 1940, no paper may be accepted for presentation at any meeting of the Society unless the title and an abstract of the paper are delivered to the office of the American Physical Society not later than the closing date stated in the printed call for that meeting.

The time allowed for the oral presentation of a contributed paper is ten minutes at most.

When two or more papers are contributed by the same member, all but one are placed on the

"supplementary programme." (A paper by two or more members is credited to the one first named in its title.) For each paper on this programme the Secretary indicates a session at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in shortened form, or may read it by title.

Titles and abstracts of the papers to be presented are given in the following pages. Proofs of these abstracts have not been submitted to the authors. After submission of proof the abstracts will be published in an early number of *The Physical Review*.

After the Providence Meeting subsequent meetings are planned as follows:

244. November, 1941. Chicago, Illinois.
245. December, 1941. Stanford University, California. Pacific Coast Meeting.
246. December, 1941. Annual Meeting. Princeton.
247. February 20–21, 1942. Detroit.

KARL K. DARROW, *Secretary*
American Physical Society
Columbia University
New York, N. Y.

April 14, 1941.

CALENDAR

For the special programme arranged for the ladies attending the meeting, see page 4.

Thursday morning, May 1—National Bureau of Standards

9:30 o'clock: Industrial Building: Session A. Papers 1–12. See pages 6–8.

9:30 o'clock: East Building: Session B. Papers 13–23. See pages 8–10.

Thursday afternoon, May 1—National Bureau of Standards

2:00 o'clock: East Building: Session C. Papers 24–34. See pages 11–13.

2:00 o'clock: Industrial Building: Session D. Papers 35–45. See pages 13–15.

2:00 o'clock: Chemistry Building: Session E. Papers 46–57. See pages 15–18.

2:00 o'clock: South Building: Room 300: Meeting of the Council.

Thursday evening, May 1—Wardman Park Hotel

6:30 o'clock: Dinner of N. R. C. Conference on Electrical Insulation: See page 3.

Friday morning, May 2—National Bureau of Standards

9:30 o'clock: Industrial Building: Session F. Papers 58–69. See pages 18–20.

9:30 o'clock: Chemistry Building: Session G. Papers 70–80. See pages 20–22.

9:30 o'clock: East Building: Session H. Papers 81–91. See pages 23–25.

Friday afternoon, May 2—National Bureau of Standards

2:00 o'clock: East Building: Session I. Papers 92–101. See pages 25–27.

2:00 o'clock: Chemistry Building: Session J. Papers 102–114. See pages 27–30.

2:00 o'clock: Industrial Buliding: Session K. Papers 115–124. See pages 30–32.

Friday evening, May 2—Wardman Park Hotel

7:00 o'clock: American Physical Society Dinner.

Saturday morning, May 3—National Academy of Sciences

9:30 o'clock: Auditorium: Session L. Papers 125–136. See pages 32–34.

9:30 o'clock: Lecture Hall: Session M. Papers 137–146. See pages 34–36.

Saturday afternoon, May 3—National Academy of Sciences

2:00 o'clock: Lecture Hall: Session N. Papers 147–158. See pages 37–39. To be read by title: Papers 159–161. See pages 39–40.

2:00 o'clock: Auditorium: Symposium of invited papers on Nuclear Energy Sources in Stars. Speakers — G. Gamow, H. A. Bethe, E. Teller, R. E. Marshak and C. L. Critchfield. See page 40.

PROGRAMME

THURSDAY MORNING AT 9:30 O'CLOCK

National Bureau of Standards

Industrial Building

Session A—Light, Particularly Line Spectra

1. Measurements of Some Optical Properties of Atmospheric Maze. E. O. HULBURT, *Naval Research Laboratory.*—By means of a telescopic photometer measurements were made in daylight of b, the brightness of a large approximately blackbody at a distance $d=3.2$ km, and of h, the brightness of the sky just above the blackbody. For visual ranges v from 3.2 to 15 km the measurements agreed with the theoretical relation

$$v/d=[\log 1/\eta]/[\log 1/(1-b/h)],$$

where $\eta=0.02$. This led to values of the attenuation of daylight in a hazy atmosphere for values of v in the above range, and to the ratio of the attenuation to that of pure air. The angular distribution of light scattered by haze was determined in two ways (1) by measuring the brightness at various angles of a searchlight beam at night, and (2) by measuring the brightness of the horizon sky at various azimuths for a moderately low sun and a cloudless sky. The distribution was much the same for haze ranging from thin to thick. It showed pronounced forward scattering as may be expected for haze particles of dimensions greater than the wave-lengths of white light.

2. Angular Distribution of Light Scattered in Liquids. L. H. DAWSON AND E. O. HULBURT, *Naval Research Laboratory.*—According to the theory of the scattering of light by isotropic particles that are small with respect to the wave-length of light, the scattered intensity at angle θ to the direction of propagation of the incident light varies as $1+\cos^2\theta$. Measurements were made for θ from about 22° to 168° for wave-lengths in the visible and near ultraviolet regions of the spectrum. For benzene, carbon disulphide and carbon tetrachloride, which were practically dust free, the $1+\cos^2\theta$ was found to be approximately true. Complete success in removing all optical impurities from water was not achieved. The purest water obtained was prepared by slow distillation in quartz and was nearly as dust free as any reported by others. It showed considerable forward scattering which was obviously due in large part to the motes. Indeed, the angular scattering distribution curve was a very sensitive indicator of the optical purity of the water.

3. Far Ultraviolet Absorption Coefficients. W. M. PRESTON, *Harvard University.*—Between 900 and 1300 angstroms there are regions where both nitrogen and oxygen are comparatively transparent to ultraviolet light. Low absorption coefficients, particularly for the lines of the Lyman series of hydrogen, are of interest in connection with the formation of the ionosphere and the origin of radio fade-outs.[1] Schneider[2] has measured the absorption of a large number of lines in air, but was limited with his apparatus to coefficients of the order of 25 cm^{-1}. In the present work it has been possible to measure coefficients one hundred times smaller by using a fast pump to evacuate a chamber separating the discharge tube and the spectrograph into which the absorbing gas was introduced. Values have been obtained for some 75 hydrogen molecular lines, and for several members of the atomic series.

[1] W. M. Preston, Phys. Rev. **57**, 887 (1940).
[2] E. C. Schneider, J. Opt. Soc. Am. **30**, 128 (1940).

4. Reflectivity of Thin Al and Cu Films in the Ultraviolet. MARY BANNING, *Johns Hopkins University.*—The reflectivity of thin films of aluminum and copper have been studied in the ultraviolet between 1000 and 2000A. The films were evaporated on glass plates in a large bell jar which also contained an open end discharge tube and which was connected through a valve to a vacuum spectrometer. After evaporation a few millimeters of H_2 or CO_2 were let into the system, and exposures taken of both the reflected and direct light from the discharge tube. Aluminum films showed a marked increase in reflectivity over previous measurements, in which the films had been exposed to air. Copper films also reflected more, and showed some structure between 1300 and 1600A. The thickness of the films did not appreciably affect the reflectivity unless the films were made very transparent.

5. Quenching and Depolarization of Mercury Resonance Radiation by Helium, Neon and Argon. LEONARD O. OLSEN, *Case School of Applied Science.*—The polarization of mercury resonance radiation excited by plane polarized light from a water-cooled d.c. mercury arc has been determined experimentally at pressures ranging from 0.1 mm to 10 mm of mercury for the rare gases listed above. The polarization as a function of applied magnetic field has been measured at several pressures for each gas and the angle of rotation of the plane of maximum polarization

RESULTS

GAS	QUENCHING CROSS SECTION	DEPOLARIZATION CROSS SECTIONS NON-ADIABATIC	ADIABATIC
Helium	Negligible	10.6×10^{-16} cm²	2.66×10^{-16} cm²
Neon	0.328×10^{-16} cm²	13.0×10^{-16} cm²	1.97×10^{-16} cm²
Argon	0.222×10^{-16} cm²	22.8×10^{-16} cm²	1.55×10^{-16} cm²

as a function of magnetic field intensity has also been observed for these pressures. These data have been used to calculate quenching and depolarizing efficiencies and cross sections for helium, neon and argon. In order to represent satisfactorily the data it is necessary to assume that the total depolarizing cross section results from adiabatic as well as non-adiabatic depolarizing collisions.

6. Lifetime of Fluorescence by an Electronic Method. R. D. RAWCLIFFE, *University of Illinois.*—An apparatus has been constructed which gives directly on a cathode-ray tube screen a decay curve of fluorescence. Incident light from a mercury arc is interrupted by a Kerr cell or a rotating slotted disk so that the "square" pulses of light enter the fluorescence cell. The fluorescent light falls on an electron multiplier tube which is connected to one pair of deflecting plates of the cathode-ray tube. A sweep circuit connected to the other pair is so arranged that the electron beam is held at one side while the incident light is shining, and then sweeps linearly across the tube while the light is off, tracing the decay curve. The sweep circuit also controls the Kerr cell. Measurements on diacetyl give a mean lifetime of fluorescence of 1.47×10^{-3} sec.$\pm$3 percent as compared with 1.65×10^{-3} sec.$\pm$10 percent, as given by Almy and Anderson.[1] The apparatus in its present form is probably limited to measurements of lifetimes longer than 10^{-6} sec.

[1] G. M. Almy and S. Anderson, J. Chem. Phys. **8**, 805 (1940).

7. A Grating Map of the Infra-red Solar Spectrum: 14 mu to 2 mu. ARTHUR ADEL, *Lowell Observatory.*—In 1935 the infra-red solar spectrum was examined with an echelette grating at the University of Michigan by Adel, Slipher and Fouts, who mapped 101 solar and terrestrial lines between 11.0 mu and 7.7 mu.[1] Continuing this work, the author has set up a Pfund type spectrometer and a Firestone Periodic Radiometer. The spectrometer is equipped with a vacuum thermopile, supplied by C. O. Lampland, and with a 2400-line echelette grating, ruled at the University of Michigan. The solar spectrum has been mapped from 14 mu to 2 mu. The atmospheric bands of carbon dioxide, ozone, nitrous oxide and water vapor have been resolved. Many solar lines appear in the new map; for example, the compound doublets $3D$-$4P$ of Na I and $6P$-$5D$ of K I. The satellite lines provide the splitting of the D terms, 1.74 cm^{-1} and 0.70 cm^{-1}, respectively. I wish to record my gratitude to Profsesors H. M. Randall and E. F. Barker, of the University of Michigan, for the grating, without which this work could not have been done.

[1] A. Adel, V. M. Slipher and O. Fouts, Phys. Rev. **49**, 288 (1936); A. Adel and V. M. Slipher, Astrophys. J. **84**, 354 (1936).

8. Interference Between Quadrupole and Magnetic Dipole Radiation. F. A. JENKINS AND S. MROZOWSKI, *University of California.*—The forbidden line λ 7330 ($^1D_2\rightarrow{}^3P_1$) of lead is composed of both magnetic dipole and electric quadrupole radiation. From the hyperfine structure Mrozowski has shown that less than 9 percent of quadrupole radiation is involved. We have investigated the Zeeman effect in order to evaluate the exact amount present. Measurements of the intensity ratio of the pure quadrupole components ($\Delta M=\pm2$) to the pure magnetic dipole ones ($\Delta M=0$) show that about 2 percent of the total radiation is quadrupole. When this figure is used to compute the relative intensities of the six mixed components ($\Delta M=\pm1$), agreement with experiment is not obtained if one merely adds the intensities of a quadrupole pattern and of a magnetic dipole pattern in the indicated proportion. Interference between the two types of radiation must be taken into account. When this is done, using theoretical equations derived by Mr. E. Gerjuoy, the agreement with the intensities predicted for 2 percent of quadrupole radiation is satisfactory. The intensity measurements were made by photographic photometry of the Fabry-Perot patterns, integrating the intensity contours where necessary. Corrections for the overlapping hyperfine structure components had to be made. Including all sources of error, we find 2.0$\pm$0.3 percent of quadrupole radiation present in this line.

9. Preliminary Study of the Doublet Structure of the Principal Series of Potassium. H. R. KRATZ AND J. E. MACK, *University of Wisconsin and Princeton University.*—A concave mirror (diameter 7.5 cm, curvature radius 4.1 m) and an especially designed prism, constituting an optical device for the production of a long absorbing path by repeated traversal[1] were mounted in a steel tube. The system was designed for, and works well with, 12 traversals (path = 50 m). With a General Electric H-6 lamp as a continuous source and with the tube filled with pure potassium plus an atmosphere of hydrogen, the absorption spectrum was studied on an E1 quartz prism spectrograph as a function of the temperature of the tube (but both ends were kept cool). Several hitherto unresolved lines were resolved into doublets, and incidentally the number of experimentally known series members was considerably extended. Quantitative studies are now being made with a 21-foot grating.

[1] H. R. Kratz and J. E. Mack, Phys. Rev. **57**, 1059A (1940).

10. The Spectra of the Rare Gases. J. B. GREEN, *Ohio State University.*—Configurations of high azimuthal quantum number in atoms with nearly closed shells have been shown theoretically by Shortley and Fried[1] to lead to levels with multiple J values in the limit, and such has been found to be true in the case of copper.[2] The rare gases show similar results in the p^5f configuration of Ne and A, but with Kr and Xe the degeneracy begins to disappear. Zeeman effects in Kr and Xe for the p^5f configurations yield g factors that indicate that the limiting type of coupling for p^5x configurations is one for which only one electrostatic and one electromagnetic parameter need be considered. There are still some anomalies in the Paschen-Back that cannot be explained by so simple a picture.

[1] G. H. Shortley and B. Fried, Phys. Rev. **54**, 739 (1938).
[2] A. G. Shenstone, Phil. Trans. Roy. Soc. **A235**, 195 (1936).

11. New Classifications in the Spectrum of Cs II. MARSHALL A. WHEATLEY* AND RALPH A. SAWYER, *Uni-*

versity of Michigan.—Previous work on the first spectrum of caesium by Sommer, by Laporte, Miller and Sawyer, and by Olthoff and Sawyer has resulted in the discovery of most of the low terms of the configurations $5p^5(^2P_{1\frac{1}{2}})5d$, $-6d$, $-7d$, $-6p$, $-6s$, $-7s$ and $-8s$, and $5p^5(^2P_{\frac{1}{2}})5d$, $-6p$, $-6d$, $-6s$ and $-7s$. In an attempt to find higher levels in this spectrum, the caesium spectrum has been rephotographed in the region from 2954A to 1857A, using as light source an electrodeless discharge in a quartz tube. Of the 850 lines measured, only 193 had previously been observed. With the aid of 36 newly established levels, 188 lines have been newly classified in the Cs II spectrum. In addition to supplying some missing members in the lower configurations, the new levels appear to belong to the $5p^5(^2P_{1\frac{1}{2}})8d$, $-7p$, $-9s$, $-10s$ and $-nf$, and $5p^5(^2P_{\frac{1}{2}})7d$, $-7p$ and $-8s$.

* Now at Wayne University.

12. New Classifications in Au I and Au II. JOHN R. PLATT* AND RALPH A. SAWYER, *University of Michigan.*—The gold spectrum emitted by a hollow cathode discharge in helium has been photographed from 600A to 10,000A. New classifications have been made in both Au I and Au II on the basis of the new lines found. In the arc spectrum, the *ns* and *nd* series discovered by Thorsen have been extended, giving for the series limit, $5d^{10}\,{}^1S_0$, a value of 74,406 cm^{-1} above the ground state of Au I. Most of the classifications of McLennan and McLay have been confirmed, and the $5d^9 6s 6p$ and $5d^9 6s 7s$ structures have been extended, while new levels of uncertain configuration have been found above the series limit. The lines assigned by McLennan and McLay to $5d^{10}5f$ transitions could not be found, and new terms have been suggested for this state. In the spark spectrum of gold, the six members of the $5d^9(^2D_{5/2})7p$ group were found, and the five missing terms were added to the $5d^8 6s^2$ structure whose lowest levels had been located by McLennan and McLay. The ground state, $5d^{10}\,{}^1S_0$, 15,039 cm^{-1} below $5d^9 6s\,{}^3D_3$, given by Sawyer and Thomson, was confirmed. In Au I, about 200 lines have been newly classified, and 38 new levels have been found. In Au II, the 82 new transitions found involve 12 new terms.

* Now at the University of Toledo.

THURSDAY MORNING AT 9:30 O'CLOCK

National Bureau of Standards

East Building

Session B—Nuclear Physics, Mainly Scattering and Capture

13. The Scattering of High Energy Neutrons by Deuterons. JACOB ROTHSTEIN, *Columbia University,* AND LLOYD MOTZ, *The College of the City of New York and Columbia University.*—The neutron-deuteron elastic scattering cross section for 2.8-Mev neutrons has been calculated using the method employed by Motz and Schwinger[1] for thermal neutrons. We assumed the interaction between all particle pairs to be of the form

$$V_{ij} = -[(1-g-g_1-g_2)P_{ij} + gP_{ij}Q_{ij} + g_1 + g_2Q_{ij}]J_0 \times \exp(-r^2/a^2),$$

where the symbols have their usual meanings. We chose $g_1 = g_2 = 0$, $g = 0.22$, $J_0 = 91.8mc^2$, and $a^2 = 0.0463$ in units $\hbar^2/Mmc^2$. The range and depth values are those of Breit and collaborators.[2] Polarization effects and p and higher wave scattering were neglected. We obtained $\sigma = 1.32 \times 10^{-24}$ cm^2. The experimental value is $\sigma_{total} = 2.17 \times 10^{-24}$ cm^2.[3] Since polarization effects are probably unimportant at these energies, it seems that the p and higher waves may be responsible for the discrepancy.

[1] L. Motz and J. Schwinger, Phys. Rev. **58**, 26 (1940).
[2] Breit, Thaxton and Eisenbud, Phys. Rev. **55**, 1018 (1939).
[3] W. H. Zinn, S. Seely and V. W. Cohen, Phys. Rev. **56**, 260 (1939).

14. Production of Mono-Energetic Protons with the Cyclotron. EDWARD C. CREUTZ AND ROBERT R. WILSON, *Princeton University.*—The proton beam of a cyclotron is ordinarily unsuited for precision measurements such as proton-proton scattering because of the large inhomogeneity of the energy.[1] However, by placing three slits in the external fringing magnetic field of the Princeton cyclotron, we have been able to select an energy interval of less than one percent and with ample intensity for scattering experiments. The three-slit arrangement, which is almost one meter long, serves also as a vacuum connection between our scattering chamber and the cyclotron. Although it is possible to calculate the energy of the protons by measuring the fringing magnetic field and the position of the slits, we find it more convenient to place a simple magnetic analyzer so that the protons enter it after passing through the scattering chamber. The energy analyzer consists of an electromagnet which produces a field of about two thousand gauss over a distance of five inches. A fluorescent screen thirty cm beyond the magnet measures the ten-cm deflection obtained. The energy can then be evaluated by the use of a simple formula which has been checked to one-half of one percent by numerical calculation.

[1] R. R. Wilson, J. App. Phys. **11**, 781 (1940).

15. Proton-Proton Scattering at 8 Mev. ROBERT R. WILSON AND EDWARD C. CREUTZ, *Princeton University.*—The mono-energetic protons described in the accompanying abstract have been used to study proton-proton collisions.

A coincidence method of counting the scattered protons is used to eliminate the neutron background due to the large internal current, impurity scattering, and slit scattering. Advantage is taken of the condition that the paths of the recoil and scattered proton are perpendicular by placing two proportional counters at a right angle to each other with a thin Cellophane target at the vertex so that only coincidences between scattered and recoil protons are registered. As the target is a thin foil, the geometry is somewhat better than when gas is used, and there is little difficulty in measuring the scattering current or in energy loss because the scattering chamber is highly evacuated. We have made an extensive study of the scattering yield as a function of the solid angle subtended by both counters and as a function of the Cellophane thickness. This indicates that multiple scattering influences the yield by a few percent if the target is thicker than 0.0005". Preliminary results indicate that the scattering yield at 8 Mev is isotropic to within two percent in the angle interval 35° to 55°.

16. Proton Recoils from High Energy Neutrons. H. TATEL, *University of Michigan.*—Two parallel plate Wynn-Williams type ionization chambers are arranged to count coincidences. High energy protons may pass through both, but short recoils do not. This makes possible the counting of a very few recoil protons from a hydrogenous scatterer near a cyclotron. When tested with alpha-particles, the apparatus showed a resolving time of 1.2×10^{-4} second. Working near the cyclotron there is an additional coincident background giving one count per six hundred events. For measuring neutron-proton scattering the neutron beam is defined by a 15-cm hole in a waterwall. The scatterer is placed four meters from the thick Be target and the detector is placed at an angle of 16° or 45° with respect to the neutron beam. It is necessary to count all recoils at these angles due to neutrons with energies between 9 and 13 Mev. For a thin (to the proton, 9 air cm at 16° and 3 air cm at 45°) hydrogen gas scatterer subtending ±2° at the detector very small corrections are necessary as the actual counting rates show.

17. Inelastic Scattering of Protons. R. H. DICKE AND JOHN MARSHALL, *University of Rochester.*—The measurement of the energies of inelastically scattered protons enables one to determine the lower energy levels of the scattering nucleus. Using a proportional counter biased so as to count only slow protons, we have obtained curves of the range in aluminum of the protons scattered from thin foils of aluminum, magnesium and several other elements. In aluminum we have found four energy levels. In magnesium, up to 3 Mev, we find only one energy level, its value being 1.4 Mev. Our values for the energy levels in Al^{27} are: 0.92 Mev, 1.93 Mev, 2.8 Mev, 3.9 Mev. The value for the level at 3.9 Mev is probably not very accurate. Wilkins and Kuerti,[1] and Wilkins and Wrenshall[2] measuring ranges in photographic emulsions obtained a value of 1.3 Mev in magnesium and 0.9 Mev for the first aluminum level.

[1] T. R. Wilkins and G. Kuerti, Phys. Rev. **57**, 1082 (1940).
[2] T. R. Wilkins and G. Wrenshall, Phys. Rev. **58**, 758 (1940).

18. Elastic and Inelastic Scattering of 2.5-Mev Neutrons. H. H. BARSCHALL, R. LADENBURG AND C. C. VAN VOORHIS, *Princeton University.*—The scattering of the 2.5-Mev $d-d$ neutrons was investigated by analyzing the distribution in energy of recoil α-particles. Since the angular distribution of 2.5-Mev neutrons scattered by helium is known, the differential cross section for elastic scattering could be determined and the amount of inelastic scattering estimated. Neutrons losing less than 200 kv in the scattering process could not be distinguished from elastically scattered neutrons. The values of $4\pi\sigma(\vartheta)$, $\sigma(\vartheta)$ being the differential scattering cross section per unit solid angle, are given in Table I in units of 10^{-24} cm². These are compared with the corresponding values for the total scattering obtained by Kikuchi, Aoki and Wakatuki. The difference gives the cross section for inelastic scattering.

TABLE I.

	Elastic Scattering		Total Scattering	
	$\vartheta=100°\pm20°$	$45°\pm10°$	100°	45°
Al	1.1 ±0.2	3.2±0.5	1.9±0.1	3.4±0.2
Fe	0.57±0.15	1.7±0.3	2.0±0.4	4.3±0.3
Cu	0.36±0.1	1.4±0.3	2.2±0.2	3.5±0.3
Pb	2.5 ±0.4	5.0±0.6	2.8±1.3	9.2±0.6

The distribution in energy of the recoils shows also, independently of this comparison, that the ratio of "inelastic" to "elastic" scattering at these angles is considerably greater in Fe and Cu than in Al and Pb.

19. Total Cross Sections for 900-kev Neutrons. W. E. GOOD* AND G. SCHARFF-GOLDHABER, *University of Illinois.*—We have measured previously[1] the total cross sections of hydrogen and carbon for Rd Th+Be neutrons. In this experiment the neutrons were detected by a hydrogen-filled ionization chamber. In the same way we have now determined the total cross sections of various elements with widely differing atomic number. Leipunsky and his collaborators[2] have studied the cross sections of a large number of elements for neutrons from Rd Th+Be with a different method. After having passed through the absorber the neutrons were slowed down in a paraffin sphere and then detected through the activation of a dysprosium target in its center. In Table I our results are compared with Leipunsky's:

TABLE I.

			σ_{tot} for 900 kev Neutrons in 10^{-24} cm²	
Element	Absorber	λ(g/cm²)	Authors	Leipunsky
$_1$H	C_nH_{2n+2}	2.43	3.70±0.35	5.5±1.1
$_4$Be	Be	3.67	2.82±0.20	1.7± .2
$_6$C	C	7.42	2.66±0.20	3.3± .4
$_{13}$Al	Al	13.10	3.39±0.25	3.1± .4
$_{29}$Cu	Cu	37.9	2.78±0.15	2.5± .4
$_{82}$Pb	Pb	50.0	6.83±0.40	5.1± .6
$_{92}$U	U	48.1	8.00±0.40	

* Now at the Westinghouse Research Laboratories.
[1] W. E. Good and G. Scharff-Goldhaber, Phys. Rev. **58**, 89 (1940).
[2] A. I. Leipunsky, J. Phys. U.S.S.R. **3**, 231 (1940).

20. Capture Cross Sections for Slow Neutrons. JOHN W. COLTMAN, *University of Illinois.*—In order to fill in the gaps in our knowledge of slow neutron capture cross sections a systematic investigation of various elements is being carried out. The cross sections of the elements have been compared with that of boron, using for the boron capture cross section a value of 600×10^{-24} cm². Any change in the measured cross section of boron will affect the results given below proportionately:

Element	$_{16}$S	$_{20}$Ca	$_{26}$Fe	$_{28}$Ni
$\sigma_{capt}\times10^{24}$ cm²	0.44±0.03	0.50±0.04	2.1±0.2	6.2±0.5
Element	$_{29}$Cu	$_{30}$Zn	$_{51}$Sb	
$\sigma_{capt}\times10^{24}$ cm²	4.3±0.3	1.0±0.06	5.3±0.3	

In the cases where a calculation from the difference between the total and scattering cross sections is possible, the values check within probable errors with those given by Goldhaber and Briggs. The values for antimony and copper are higher than those obtained by the method of induced radioactivity.[1,2] This method would give too low values for the cross sections if K-capture activity were present, as is to be expected for these cases.

[1] R. D. O'Neal and M. Goldhaber, Phys. Rev. **59**, 102 (1941).
[2] F. Rasetti, Phys. Rev. **58**, 869 (1940).

21. Velocity Dependence of Slow Neutrons Capture Cross Section of Boron. E. A. LUEBKE, J. H. MANLEY AND L. J. HAWORTH, *University of Illinois.*—The absorption of slow neutrons in boron as a function of neutron velocity has been investigated, using a modulated source of neutrons from the Illinois linear accelerator and special circuits[1] for making velocity measurements. The detector is a parallel plate BF_3 ionization chamber with a sensitive volume of 1100 cm³. A source-detector distance of 250 cm was used with a neutron pulse width of 150 microseconds. Observations were made in a velocity range 1 to 10 km/sec. with time scale of 150 microsecond intervals. Within the limits of error, the data obtained indicate the velocity dependence of the slow neutron capture cross section of boron to be $1/v$. This is in agreement with the experimental results of Alvarez[2] and differs from those of Fertel, Gibbs, Moon, Thomson and Wynn-Williams.[3]

[1] L. J. Haworth, J. H. Manley, M. P. Vore and E. A. Luebke, Phys. Rev. **57**, 1075 (1940).
[2] L. W. Alvarez, Phys. Rev. **54**, 609 (1938).
[3] G. E. F. Fertel, D. F. Gibbs, P. B. Moon, G. P. Thomson and C. E. Wynn-Williams, Proc. Roy. Soc. **175**, 316 (1940).

22. Inflation of Heavy Nuclei. R. D. PRESENT, *Harvard University.*—Deviations from the law that the nuclear volume is propotironal to the number of particles ($R=r_0A^{\frac{1}{3}}$) occur when the Coulomb repulsion, the surface tension pressure and the neutron excess are considered in addition to the usual exchange forces for $N=Z$. These effects are estimated from Euler's statistical treatment[1] which gives an inverse compressibility for nuclear matter $A^{-1}R^2(d^2E/dR^2)=70$ Mev. The corrections to the nuclear radius are proportional to the compressibility and (assuming constant thickness of the surface layer) all three corrections tend to increase r_0 with increasing A. The particle radius beneath the surface layer is given by:

$$r_0=\bar{r}_0\{1+0.010Z^2/A^{4/3}-0.3A^{-1/3}+0.8[(N-Z)/A]^2\}.$$

r_0 increases by 9 percent from Fe^{56} to Pb^{207}. For light nuclei where the surface correction is made differently,[2] r_0 increases with decreasing A, by 5 percent from Fe^{56} to O^{16}. Nuclear radii determined from elastic scattering of fast neutrons are expected to be 2×10^{-13} cm larger than the statistical radii R. Experiments of Wakatuki,[3] interpreted by the Placzek-Bethe shadow formula, show a 12 percent increase of r_0 from Fe^{56} to Pb^{207}. The Barkas-Bethe radii for light positron emitters, Weisskopf-Ewing radii for intermediate nuclei and Gamow radii for radioactive nuclei are consistent with the calculated corrections ($\bar{r}_0=1.4\times10^{-13}$ cm).

[1] H. Euler, Zeits. f. Physik **105**, 553 (1937).
[2] S. Flügge, Zeits. f. Physik **96**, 459 (1935).
[3] T. Wakatuki, Phys.-Math. Soc. Japan **22**, 430 (1940).

23. The Nuclear Radii of Light Elements. D. R. ELLIOTT, *Purdue University.*—The differences in mass defects between isobaric pairs of nuclei of the type $Z=N\pm1$ (N the number of neutrons) have been measured by various workers.[1] It is generally assumed that these differences are due only to the change in Coulomb energy when the extra proton is replaced by a neutron. Under this assumption, the radii of these nuclei can be calculated with the help of specific nuclear models. If the nucleus is considered as a homogeneous sphere with a uniform charge distribution, the difference in Coulomb emergy is

$$E_C=\frac{6}{5}\frac{Z-1}{R_0}.$$

On the other hand if a slightly modified form of Bethe's[2] central core nucleus, which includes a correction for the extension of the wave function of the "extra" neutron, is used, one obtains the formula

$$E_C=\frac{3(Z-1)}{R_0}f\left(\frac{1}{\epsilon R_0}\right).$$

The radii of the nuclei between $Z=2$ and $Z=21$ have been calculated on the basis of these formulae. For the first model, the volume per particle turns out to be larger for low atomic numbers, but has many local variations. The second model yields a volume per particle which is constant within a given Hartree shell, but changes slightly from one shell to the next.

[1] White, Creutz, Delssaso and Wilson, Phys. Rev. **59**, 63 (1941); D. R. Elliott and L. D. P. King, Phys. Rev. **59**, 403 (1941); G. T. Seaborg, Chem. Rev. **27**, 199 (1940).
[2] H. A. Bethe, Phys. Rev. **54**, 436 (1938).

THURSDAY AFTERNOON AT 2:00 O'CLOCK

National Bureau of Standards

East Building

Session C—Diverse Topics in Nuclear Physics

24. Neutron Shielding. M. STANLEY LIVINGSTON, *Massachusetts Institute of Technology.*—Neutron absorption coefficients in paraffin obtained from unpublished data of Aebersold are used to determine the attenuation in water tanks, now generally used for cyclotron shielding. Production and absorption in the tanks of the 2.2-Mev gamma-radiation from the $H(n, \gamma)$ reaction is calculated from the absorption coefficients. The ionization behind the tanks resulting from this secondary gamma-radiation is found to be much greater than from the residual fast neutrons. Concentrations of borate materials required to reduce the slow neutron and hence the gamma-ray intensity to a few percent are determined. The scattering of neutrons around the shielding tanks is considered and overhead and side tank requirements are estimated. The accepted safe dose rates of 0.1 roentgen per day for gammas and 0.01 roentgen per day for neutrons are reduced to number of quanta per second and used as intensity units. Using the reported neutron yields from cyclotrons the intensity behind the shields due to each component of the radiation can be determined. Gamma-rays produced by neutrons scattered around the tanks or escaping through apertures are shown to contribute the most ionization.

25. An Automatic Frequency Control for Cyclotron R.F. Power Supply. R. B. JACQUES, *Ohio State University.* (*Introduced by M. L. Pool.*)—A control device has been constructed to correct automatically for the drift in frequency of a power oscillator due to changes in the capacitive and inductive load reactances. These changes are a result of load heating effects encountered in using the power oscillator to provide driving power for a cyclotron. The control unit consists of a local electron coupled oscillator circuit, tuned to a frequency 5000 cycles below the fundamental frequency of the power oscillator. This provides a heterodyne signal of 5000 cycles, which is amplified through a conventional high gain audio-amplifier. This amplified signal is fed into a balanced bridge circuit, consisting of capacitive and inductive reactances resonated at 5000 cycles. If the frequency of the power oscillator varies due to load reactance changes, the heterodyne signal frequency will also vary in frequency in direct proportion, and the bridge circuit will become unbalanced. This unbalanced voltage is applied through two diodes across a load resistor in the grid circuits of two relay vacuum tubes, normally biased to cut-off. These relay tubes operate a reversible motor, through power relays, driving a load correction capacitor in the proper direction to compensate for the frequency change.

26. Flow of a Radioactive Gas Through a Tube. W. H. FURRY, *Harvard University.*—If a gas carrying a radioactive substance of long life flows at a uniform rate through a tube of small radius, the activity per unit length varies as $e^{-z/l}$, with $1 = V/\partial\pi a^2\lambda$; here V is volume per second, a is radius, and λ is decay constant. This law is never exact for nonturbulent flow, because the speed of flow is not everywhere equal to $V/\partial\pi a^2$, but varies from $2V/\partial\pi a^2$ along the axis to zero at the wall. The simple exponential law holds only in the limit $a^2\lambda/D = S \to 0$, where D is the diffusion coefficient. In general, the activity varies as $\Sigma A_j e^{-z/b_j}$, where the A_j depend on the precise way in which the gas entered the tube. For small S, $b_0/2 = 1 - S/48 + \cdots$, $b_1/b_0 \sim 0.1S$, and $|A_1|/A_0 \sim 0.02S$. For larger values of S the b's become comparable in magnitude, and so do the A's; the situation is then decidedly complicated. In experimental practice the reasonable procedure is to keep S small. This can always be done very easily if the lifetime is longer than a few seconds.

27. Isolation of Pure Radioactive Strontium and Barium. J. D. KURBATOV, M. L. POOL AND H. B. LAW, *Ohio State University.*—In previous work radium and thorium X were isolated from mother elements without addition of carriers.[1] In this investigation radioactive strontium and barium were obtained in pure state. Strontium oxide was activated with deuterons. Yttrium isotopes were separated as radiocolloids from strontium without the addition of rare earths as carriers. Adsorption isotherms of strontium by ferric hydroxide at different pH's were obtained, using $_{38}Sr^{89}$ of known activity diluted with stable strontium. The number of strontium atoms adsorbed by unit weight of precipitated iron was established. Yttrium active isotopes were precipitated in the presence of ferric chloride, and $_{38}Sr^{87}$ was isolated in pure state at pH 6.8. After determination of the decay period, $_{38}Sr^{87}$ was quantitatively adsorbed from solution by new portions of ferric hydroxide at pH 9. Radioactive barium ($_{56}Ba^{139}$) was similarly isolated in pure state from activated lanthanum. The adsorption process is offered (1) for quantitative separation of radioelements in pure state, without addition of carriers, and (2) as a means of obtaining radioelements in concentrated form, rather than the method of recrystallization of isomorphic systems based on the Berthelot-Nernst law of distribution. A new formulation of the adsorption law of radioelements is suggested.

[1] J. Kurbatov, "Adsorption of thorium X by ferric hydroxide at different pH." Am. J. Phys. Chem. **36**, 1241 (1932).

28. Magnetic Beta-Ray Spectrometer. RALPH L. MCCREARY, *University of Rochester.*—A beta-ray spectrometer has been constructed which is especially adapted for the study of nuclear beta-rays and internal conversion electrons. It is of the 90° focusing type and employs a

thin window counter as a detector. The counter forms a separate unit and is held in place by the vacuum seal. The chamber contains an adjustable slit system for defining the electron beam. Because of the leakage flux at the physical boundary of the magnetic field, the source holder and counter are arranged so that they may be moved to the position of best focus for the particular magnetic field used. The source holder is so arranged that short-lived activities may be studied by successive replacement with new samples. Results obtained will be discussed.

29. Range of Intermediate Ions. J. H. M. BRUNINGS AND J. K. KNIPP, *Purdue University.*—The velocity-range relation in air of neon ions has been calculated by assuming the effective charge of the ion for a given velocity to be determined by the relation $V_e=\gamma V$, where V_e is the velocity of the electron which is being captured and lost, V is the particle velocity and γ is a parameter which in principle might be determined from the cross sections for capture and loss but which actually is determined from experiment.[1] The curves obtained are compared with experimental data on neon ions produced in recoil from alpha-particles.[2] These data are represented very well up to $V=4\times10^8$ cm/sec. by a single value of the parameter ($\gamma=1.15$). However, above this velocity a somewhat smaller value of the parameter is required. The value $\gamma=1.15$ is approximately correct for the first few p-electrons of all the intermediate ions for which data exist (C^{12}, N^{14}, O^{16}, F^{19}, Ne^{20}). Data at higher degrees of ionization are incomplete but they seem to indicate throughout the necessity of a smaller average value of γ for the inner electrons.

[1] Knipp and Teller, Phys. Rev. **59**, 659 (1941).
[2] W. W. Eaton, Phys. Rev. **48**, 921 (1935); J. T. McCarthy, Phys. Rev. **53**, 30 (1938).

30. Comparative Study of Photo-Neutron Sources. R. D. O'NEAL, *University of Illinois.*—The slowing down of the photo-neutrons from 100 mg Ra+Be, 100 mg Ra+D_2O, 10 mg Rd Th+D_2O, and Y+Be were studied by the method of Amaldi and Fermi, using an indium detector. An intense yttrium gamma-ray source was very kindly loaned by Dr. Pecher. The number of neutrons from this source surrounded by beryllium as measured by the integral under the Amaldi-Fermi curve was compared with the number of neutrons from Ra+Be measured in the same manner. This ratio was approximately equal to the ratio of the hard gamma-ray intensities of these sources (as measured through 6 mm of lead). This is in agreement with the result that the energy of the yttrium gamma-rays, 1.87±.05 Mev,[1] is intermediate between the energy of the radium gamma-rays responsible for photo-neutrons. An attempt was made to determine whether the 2.2-Mev gamma-ray of radium gives any appreciable contribution to the neutrons from Ra+D_2O. A comparison was made between the curves for Ra+D_2O and Rd Th+D_2O and between Ra+D_2O and Ra+Be. Curves for both C and D neutrons were studied but no evidence was found for low energy neutrons produced by the 2.2-Mev gamma-rays.

[1] See abstract by Scharff-Goldhaber.

31. Partial Separation of the Oxygen Isotopes by Thermal Diffusion. S. B. WELLES, *Yale University.*—With an eighteen-meter column, O^{18} has been enriched from the ordinary concentration of 0.2 percent to 14 percent and O^{17} from 0.04 percent to 0.8 percent. The former increase was determined by the mass spectrometer, the latter by the increased activity of F^{18} produced in the nuclear reaction $O^{17}(d, n)F^{18}$. The time rate of increase of the concentration of O^{18} was characterized by a step-wise nature, which arises from the staggering of the six three-meter tubes convectively coupled in series. The theory of "staggering" will be discussed. An investigation is being made of the proton groups from the enriched oxygen under deuteron bombardment.

32. Improved Counting Rate Meter for Radioactivity Detection. ARTHUR F. KIP AND ROBLEY D. EVANS, *Massachusetts Institute of Technology.*—The design of the counting rate meter[1] has been improved to give greater ease of operation, stability, range and linearity. The output current, which is proportional to the average counting rate of the radioactive sample being measured, is fed through a vacuum tube voltmeter, whose maximum output is 5 ma. This increased output current allows replacement of photographic recording, with its inherent delays, by a commercial 5-ma pen and ink recorder, which is very easy to monitor visually. Use of the vacuum tube voltmeter in the output circuit permits reduction of the integrating condenser from 100 μf to 2 μf. Time constants of 15, 30 and 60 seconds are now used for the high, medium and low counting rate ranges. Seven output ranges are provided, varying from 200 to 20,000 counts per minute for full scale deflection, and the amplifier is linear over the entire range. Continuously variable high voltage, from 500 to 2000 volts, is provided by a thermionic stabilizer. The amplifier is entirely a.c. operated.

[1] Evans and Alder, Rev. Sci. Inst. **10**, 332 (1939).

33. Radioactivity of Rocks. ROBLEY D. EVANS AND CLARK GOODMAN, *Massachusetts Institute of Technology.*—Although numerous previous measurements of the radioactivity of terrestrial materials have been made, most of these researches are of qualitative value only in their applications to geology, geophysics, and cosmology because of inadequate recognition of the analytical care necessary in order to obtain reliable results. In recent studies of the radioactivity of terrestrial materials, a systematic program of standardization, calibration, and interchecking has been followed throughout. By combining our newer measurements with the limited number of well-authenticated earlier analyses available, average values have been obtained as follows: $1.37\pm0.17\times10^{-12}$ g Ra/g for 43 acidic igneous rocks, $0.51\pm0.05\times10^{-12}$ g Ra/g for 7 intermediate igneous rocks, $0.38\pm0.03\times10^{-12}$ g Ra/g for 54 basic igneous rocks, and $0.57\pm0.08\times10^{-12}$ g Ra/g for 28 sedimentary rocks; $3.0\pm0.3\times10^{-6}$ g U/g, $13.\pm2.0\times10^{-6}$ g Th/g, and a Th/U ratio of 5.0 for 26 acidic igneous rocks; $1.4\pm0.2\times10^{-6}$ g U/g, $4.4\pm1.2\times10^{-6}$ g Th/g, and a Th/U ratio of 2.6 for 6 intermediate igneous rocks; $0.96\pm0.11\times10^{-6}$ g U/g, $3.9\pm0.6\times10^{-6}$ g Th/g, and a Th/U ratio of

4.0 for 34 basic igneous rocks. The Th and U values are substantially lower and the Th/U ratios are higher than those obtained by Jeffreys[1] in a compilation of most of the measurements reported prior to 1936. Estimates are made of the rate of production of heat by radioactive decay based on the above average values for the different rock types.

[1] H. Jeffreys, Gerlands Beit. zur Geophysik **47**, 149–170 (1936).

34. Helium Age Measurements. CLARK GOODMAN, ROBLEY D. EVANS AND PATRICK M. HURLEY, *Massachusetts Institute of Technology.*—Following discard of the previous helium time scale because of invalidation of the radioactivity measurements,[1] an attempt was made to establish a new scale from alpha-helium age determinations on a variety of rocks. Substantially lower helium age-ratios were obtained for acidic rocks than for corresponding basic rocks and both types gave values considerably lower than the equivalent lead age-ratios for radioactive minerals. Mean age-ratios of 103 million years for pyroxene separates and 36 million years for feldspar separates were obtained for six samples of Triassic diabase. This discrepancy between age-ratios for geologically contemporaneous materials appears to be due to a difference in helium retentivity. Six samples of late Triassic magnetite from ore occurrences in West Virginia, Pennsylvania, and Nova Scotia gave age-ratios closely grouped about a mean value of 134 million years. The constant age-ratio, despite widely varying contents of radium and thorium, suggests that magnetite retains essentially all of its radiogenic helium. Additional evidence on the high helium retentivity of magnetite is provided by specimens of differing geological ages. Age-ratios on some 30 magnetites show a sequence and spacing compatible with geological knowledge, and the results are in fair agreement with corresponding lead age-ratios.

[1] R. D. Evans, C. Goodman, N. B. Keevil, A. C. Lane, and W. D. Urry, Phys. Rev. **55**, 931–946 (1939).

THURSDAY AFTERNOON AT 2:00 O'CLOCK

National Bureau of Standards

Industrial Building

Session D—Instruments and Diverse Topics

35. An Analysis of the Amplification of Exponential Pulses. CHESTER H. PAGE, *Lafayette College*—A counter-pulse amplifier with fixed bias on the tube grids has the disadvantage of changing its gain noticeably as the tubes and batteries grow old. Self-bias obtained from a resistor in the cathode circuit gives a much stabler arrangement; one whose characteristics are little affected by tube replacements. A study is made of the pulse shape amplification characteristics of a self-biased stage, which is inherently degenerative by virtue of the cathode network, and it is shown that an unconventional cathode network has advantages. By proper adjustment of the time constant of the cathode network, backlash may be reduced and the time resolution greatly increased without appreciable loss in gain as compared with a fixed bias stage.

36. Apparatus for Studying Surface Tension at High Pressures. LAURENCE B. HEILPRIN, *Harvard University.*—A high-pressure bomb has been constructed for visual or photographic study of surface tension in a two-phase liquid-liquid system. Mercury and a lighter, transparent liquid are sealed in a glass capillometer in such a way that hydrostatic pressure is transmitted inside and out. The capillometer consists of two vertical glass capillary tubes of different internal radii, with a scale mounted parallel between them. Tubes and scale are photographed through glass windows. Difference in height, and shape of meniscus of the two mercury columns are measured as a function of pressure. The thermodynamic relation

$$(\partial\gamma/\partial p)_{T,A} = (\partial V/\partial A)_{T,p},$$

where γ is surface tension, p pressure, T temperature, V volume of a mass of liquid, and A its area, indicates difference of molecular volume in the interior and at the surface of a liquid. The system mercury-water has been investigated over a range of 2500 atmospheres at room temperature. Preliminary results indicate a decrease with pressure, in mercury-water interfacial surface tension.

37. Electrical Conduction in the Glass Insulation of Resistance Thermometers. HAROLD J. HOGE, *National Bureau of Standards.*—The platinum leads of many resistance thermometers pass through a soft glass seal, which during measurements is subjected to an e.m.f. of the order of 0.1 volt. Above 300°C, conduction in the glass becomes noticeable and increases rapidly with the temperature. The effect was studied in similar seals with the thermometer coil omitted. The apparent conduction consists of a displacement current and probably also of an ionic current. Application of a constant potential causes a large current to flow, which decreases rapidly for several minutes and is still measurable after an hour or more. Upon removal of the e.m.f. and substitution of a resistance, the discharge current varies with time in much the same way. Similar behavior has long been observed in the case of Leyden jars. The rate of discharge is greatly increased by heating above

the charging temperature. Two simple precautions are recommended when thermometers of this type are calibrated at the sulfur point: (a) always to apply the e.m.f. in the same direction, and (b) to allow the current to flow for several minutes before taking the first measurement, so that the displacement current will have fallen to a relatively low value.

38. A Method of Making Direct Measurements of the Thermal Coefficient of the Index of Refraction, with Some Results for Distilled Water. JOHN B. HAWKES, *Stevens Institute of Technology.*—An interferometer of the Jamin type is used to measure directly the thermal coefficient of the index of refraction of distilled water. The chief advantage of this method, in addition to a high precision, is its great sensitivity to anomalies in the index-temperature relation. The method is particularly adaptable to measurements at temperatures below the dew point, for which fogging of the windows is a serious problem in the conventional refractometers. The refractive index of water was measured between 40°C and 0°C. The refractive index above the temperature of maximum density is in complete agreement with established values. The behavior below 4°C shows peculiarities of sufficient magnitude to warrant further investigation.

39. Characteristics of Two New Photoflash Lamps. W. E. FORSYTHE AND M. ADELAIDE EASLEY, *Lamp Department, General Electric Company.*—Two new types of photoflash lamps have been developed. In the first of these new lamps, the foil or wire filling has been replaced with shredded foil. This newer type of filling is not only shredded and put into the bulb automatically, but the resulting lamps are an improvement over the older types. The second of these new lamps is the all primer photoflash lamp in which all the light is produced by the new type of primer. This lamp has a very short time to peak and a short duration which gives it some advantages for certain types of synchronization. Data on some of these newer lamps are given in the table.

No. and Bulb Size	Total Light Lum. Sec.	Maximum Flux Lumens	Time to Peak	Effective Duration	Color Temp.
SM–B11	3,500	0.6×10^6	5 ms.	4 ms.	3550°K
5–B11	18,000	1.2×10^6	20 ms.	10 ms.	3800
16A–A17	45,000	2.5×10^6	20 ms.	14 ms.	3800
50–A21	100,000	6.0×10^6	30 ms.	14 ms.	3800
6–B11	—	— —	—	—	—

40. Bridge Method for Specific Heat of Wire Samples. B. KURRELMEYER, W. H. MAIS, AND E. H. GREEN, *Brooklyn College.*—A metal wire, of 2 to 4 mil diameter, enclosed in an evacuated bulb, is placed in one arm of a Wheatstone bridge and brought to the temperature at which its heat capacity is to be determined. With the bridge balanced, galvanometer key closed, and battery key open, a charged condenser is connected across the battery terminals of the bridge. The heat capacity is evaluated from the resulting ballistic deflection. In an alternative procedure, the bridge is initially unbalanced so that discharge of the condenser gives zero deflection. The resistance of the wire must be known as a function of temperature, and this will in general be the most severe limitation on the accuracy of the method. The thermal time constant of the wire and the time constant of the condenser discharge are such that heat losses are negligible at ordinary temperatures. The method has been tested on pure platinum, tungsten, and iron in the neighborhood of room temperature. So far an accuracy of 0.5 percent has been obtained. The internal consistency appears to be much better. The method will be applied to the study of iron in magnetic fields.

41. A Large Recording Spectrograph for the Infra-Red to 15μ. E. D. MCALISTER,[1] G. L. MATHESON, AND W. J. SWEENEY, *Standard Oil Development Company.*—An infrared spectrograph that will be of most practical value in industrial work must provide the highest resolution consistent with a wide wave-length range. These considerations led to the construction of a Littrow instrument employing a large prism of "artificial" rocksalt (base dimension equivalent to 30 centimeters). A resolving power equal to the theoretical limit of the prism was achieved for all wavelengths greater than 2.5μ (6 cm^{-1}, 1 cm^{-1} and 0.3 cm^{-1} at 2.7, 6, and 14μ, respectively). The improvements in detail necessary for this practical balance between prism size, aperture and sensitivity of detection are described. The instrument is very useful in the visible and ultraviolet regions, although a perceptible inhomogeneity in refractive index of the prism material (probably due to strain) prevents attainment of the theoretical resolution here.

[1] Consultant from the Smithsonian Institution.

42. Radiant Energy Measurements with Thermopiles. N. C. BEESE, *Westinghouse Lamp Division.*—The ultraviolet energy from several mercury vapor lamps was measured by the use of thermopiles and filters. It was discovered that lower values were always obtained when the thermopiles were evacuated than when they were filled with air. The difference was of the order of 20 to 30 percent. A possible explanation is that the carbon coating on the thermopile surface passes the radiations from the Standard lamp, chiefly infra-red, to the thermal junctions whether the thermopile is evacuated or filled with air. Ultraviolet radiations on the other hand are absorbed by the outer surface layers and the energy is transmitted to the active thermal junctions by conduction through the lower layers of carbon particles and by the gas molecules in the porous layer of soot. When evacuated, the effect of the gas molecules in transferring energy through the coating is lost, and so causes a reading that is too low.

43. Dielectric Constant of a Space Charge Rotating in a Magnetic Field. JOHN P. BLEWETT AND SIMON RAMO, *General Electric Company.*—In a recent paper in the Physical Review,[1] the authors presented a theoretical discussion of the behavior of a space charge of uniform density rotating under the influence of a uniform mag-

netic field. The solutions of the field and force equations were found to be somewhat similar to the free space wave guide solutions. In particular, it was noted that the space charge behaves toward an E_0 type wave as though it were a medium whose dielectric constant is less than unity by an amount depending on magnetic field and frequency. For convenient values of magnetic field and frequency, this dielectric constant may easily become zero, or even attain negative values. An experimental study of this phenomenon for a frequency of 600 Mc and magnetic fields of a few hundred gauss gives results in agreement with the theoretical predictions.

[1] Phys. Rev. **57**, 635 (1940).

44. Determination of Diffusion Coefficients. R. T. ELLICKSON AND B. SERIN, *Polytechnic Institute of Brooklyn.*—In a paper presented elsewhere[1] the following equation was derived from Fick's law and shown so apply to diffusion in a slab of thickness L:

$$1-\alpha=8/\pi^2 \sum_{n \text{ odd}} (1/n^2) \exp\left[-n^2\pi^2Dt/L^2\right],$$

where α is the fraction of the diffusion process completed at time t and D the diffusion coefficient. It is clear that for large values of t all terms in the sum are negligible compared with the first, and a plot of $\log(1-\alpha)$ against t yields a straight line with slope proportional to D. The higher terms can be neglected for values of t corresponding to $\alpha \gtrsim 0.3$. However, many experiments do not yield values of α greater than 0.3. A method will be described which gives a value of D for each experimentally determined value of α, regardless of the magnitude of α. The method will be applied to various diffusion data.

[1] R. Ellickson and R. Ward, St. Louis Meeting of Am. Chem. Soc., April, 1940.

45. Molybdenite as a New Lubricant. M. E. BELL AND J. H. FINDLAY, *Westinghouse Lamp Division, Westinghouse Electric & Manufacturing Company.*—In designing a bearing for a rotating anode x-ray tube, oils and greases were discarded on account of their high vapor pressures. All tubes containing these substances ultimately became gassy. Unlubricated ball bearings made of tool steel were tried with only fair results. Experiments indicated that when metal bearing surfaces are thoroughly cleaned, outgassed and used in a vacuum, welding action occurs between adjacent rolling or sliding surfaces. Successive welds and breaks roughen the surfaces and soon create high friction. The need for a good lubricant with a low vapor pressure and high chemical stability became apparent. Molybdenite was chosen for tests because of its laminar crystal structure. Each lamina consists of a layer of molybdenum atoms with a layer of sulphur atoms on each side. One of these lamina adheres strongly to a metallic surface because of a strong metal-sulphur bond. Lamina on adjacent metal surfaces slip easily over each other because of the weakness of the sulphur to sulphur bond. Bearings in a vacuum coated with molybdenite have operated extremely well. The use of molybdenite as a lubricant is not necessarily restricted to a vacuum.

THURSDAY AFTERNOON AT 2:00 O'CLOCK

National Bureau of Standards

Chemistry Building

Session E—Molecules

46. On the Silicon Oxide Bands. L. H. WOODS, *University of Chicago.* (*Introduced by S. Mrozowski.*)—Pankhurst[1] has described shortly a band spectrum believed by him to belong to an oxide of silicon, possibly SiO_2. A better excitation of the same bands has been obtained from a similar source (a high voltage uncondensed discharge through a constriction in a quartz tube), but in an atmosphere of helium instead of hydrogen. These bands have been photographed on the 30-foot, 30,000 lines/inch grating spectrograph. A band around λ3840 has been resolved in the first and second order and found to be a (0,0) transition (overlapped by a weak 1,1 band) of the type $^2\Sigma \rightarrow {}^2\Sigma$ with the values $\nu_0=26{,}015.05$ cm, $B'=0.7180$, $B''=0.7253$. The coefficients of the spin doubling for the two states are $\gamma'=\pm 0.005$, $\gamma''=\mp 0.006$. The difference in sign indicates the presence of a perturbing $^2\Pi$ state lying between the upper and lower levels. The doublet structure and the B values prove that the emitter is SiO^+. A less intense group of bands λ4270 has also been resolved but not yet analyzed. The relative intensities in hydrogen and in helium of both groups of bands indicate that the group λ4270 is not emitted by an ionized molecule. Of the two remaining possibilities, neutral SiO and SiO_2, the distance of the lines and the excitation conditions indicate that neutral SiO is much more probable.

[1] R. C. Pankhurst, Proc. Phys. Soc. **52**, 707 (1940).

47. Rotational Analysis of a System of CO_2 Bands. S. MROZOWSKI, *University of Chicago.*—The band spectrum of CO_2 has been investigated in the second order of the 30-foot Chicago grating, with a practical resolving power of 350,000. Nearly all the bands previously reported by Smyth,[1] and in addition a few new ones, were obtained. A partial vibrational analysis shows that more than forty of

these belong to an extended system of the type $^2\Pi \rightarrow {}^2\Pi$. Of these, three pairs of bands (previously investigated with lower resolving power by Schmid in this laboratory) have been analyzed so far. The analysis, thanks to the complete resolution, now leaves no doubts about the numbering of the lines. The lower $^2\Pi$ appears to be the ground state $^2\Pi_g$ of the molecule CO_2^+, the upper $^2\Pi$ is the first excited state $^2\Pi_u$ of this molecule predicted by Mulliken. The λ-doubling in $^2\Pi_u$ is bigger than in $^2\Pi_g$ and increases fast with the vibrational energy. The results of the analysis are: $\nu_0^{0,0}=28{,}532.59$ cm^{-1}, $\nu_0^{1,0}=29{,}659.28$, $\nu_0^{2,0}=30{,}781.96$ (all $^2\Pi_{3/2}\rightarrow{}^2\Pi_{3/2}$); and $\nu_0^{0,0}=28{,}468.51$, $\nu_0^{1,0}=29{,}594.28$, $\nu_0^{2,0}=30715.22$ (all $^2\Pi_{1/2}\rightarrow{}^2\Pi_{1/2}$), the upper indices indicating the quantum numbers of the symmetrical vibration. Further for $^2\Pi_{3/2g}$, $B_0=0.3795$; $^2\Pi_{1/2g}$, $B_0=0.3809$; $^2\Pi_{3/2u}$, $B_0=0.3486$, $B_1=0.3475$, $B_2=0.3463$; $^2\Pi_{1/2u}$, $B_0=0.3501$, $B_1=0.3489$, $B_2=0.3476$.

[1] H. D. Smyth, Phys. Rev. **38**, 2000 (1931).

48. Rotational Analysis of the CO_2^+ Band near 2900A. F. Bueso-Sanllehí, *University of Chicago.*—A rotational analysis of the CO_2^+ doublet band near λ2896 and λ2882 has been made. The band was photographed in the third order of the 30-ft. grating spectrograph in Ryerson Laboratory with a dispersion of 0.22 A/mm. The structure is explained by a $^2\Sigma_u^+\rightarrow{}^2\Pi_g$ transition, where the latter is the ground state of CO_2^+. The close agreement of the $\Delta F'''$s with Mrozowski's (see preceding abstract) proves that the bands have the same lower state. In addition there are much weaker bands superposed which may be ascribed to transitions between higher vibrational states. Alternate lines are missing as expected for $^2\Sigma$ and the zero spin of the oxygen nuclei. A number of perturbations are observed, showing displacements and weakenings of lines. These are probably caused by higher vibrational levels of the $^2\Pi_u$ state (see preceding abstract) which lies immediately below the $^2\Sigma_u^+$. The weakness of some of the perturbed lines suggests that the perturbation is sometimes accompanied by predissociation. A tentative value of the spin doubling in the upper $^2\Sigma_u^+$ state has been obtained ($\Delta\nu=0.020$ $(K+\frac{1}{2})$). The B values of the upper and lower states are very nearly equal, B' being slightly smaller.

49. Vibrational Analysis of the Absorption System of Sulphur Dioxide at λ3400–2900. N. Metropolis, *University of Chicago.*—Photographs of the bands of sulphur dioxide in the region of λ3400–2900 have been taken under low, medium and high dispersion, both at room temperature and at 200°K; the pressure of the absorbing gas was varied from 0.3 mm to 480 mm. Thirty bands can be represented by the formula

$$\nu=29622+770v_1+320v_2+818v_3-7v_1^2 -2.5v_2^2-20v_1v_2-25v_2v_3-15v_1v_3,$$

where v_1, v_2, v_3, are the quantum numbers of the symmetric valence, the deformation and the antisymmetric vibrations, respectively. The three fundamental frequencies for infinitesimal vibrations are $\nu_1=794$, $\nu_2=345$ and $\nu_3=838$ cm^{-1}. In addition, twelve bands have been identified that correspond to transitions from excited vibrational levels in the normal state. The relatively long v_1 and v_2 progressions indicate that both the bond distance and angle have changed considerably in the transition to the excited electronic state. The vibrationless transition at 29,622 cm^{-1} is weak, as one would have expected from considerations of the Franck-Condon principle. Substituting the three fundamental frequencies in the valence force potential, one obtains a value of 100° for the apex angle in the upper state, as compared with 120° in the normal state. The absence of any regularity in the rotational structure supports the conclusion that the molecule has become a more asymmetrical top.

50. Species Classification and Rotational Energy Level Patterns of Triatomic Molecules. Robert S. Mulliken, *University of Chicago.*—The quantized energy levels of symmetrical and asymmetrical tops are discussed from the viewpoint of their classification into species defined by symmetry operations. These are then used in a discussion of the rotational levels of symmetrical nonlinear triatomic molecules AB_2. Using SO_2 as an example, the pattern of rotational levels is studied as a function of the apex angle 2α (near-prolate-symmetrical case for large α, oblate or near-oblate case for intermediate α, second near-prolate case for small α). The classification of the *over-all* wave functions of the levels with respect to exchange of equal nuclei and for inversion is then considered. This gives rise to level-patterns like those of diatomic and linear molecules in the first near-prolate case, but of interesting unfamiliar types (expected also in molecules such as BCl_3 or NH_3) in the oblate case, and of relatively unfamiliar types (known for the molecule H_2CO) in the second near-prolate case. The concept of gryo-vibronic species, and a corresponding nomenclature, are then introduced. Finally, the problem of the correlation between states of linear and nonlinear AB_2 molecules is considered, and a correlation diagram relating the sets of gyro-vibronic levels of the two cases is obtained.

51. Absorption Spectrum of Fluorobenzene in the Near Ultraviolet. H. Sponer and S. H. Wollman, *Duke University.*—The absorption spectrum of C_6H_5F at 2750–2380A was photographed in the first order of a 3-m grating spectrograph. As in monochlorobenzene the band system corresponds to an electronic transition $A_1\rightarrow B_2$. In agreement with this assignment to an allowed transition the 0,0 band appears strongly at 37,818 cm^{-1}. Several progressions of totally symmetrical vibrations occur involving particularly frequencies of 913, 966 and 1228 cm^{-1}. Probably all three, but surely the first two, belong to totally symmetrical carbon vibrations in the upper state. In contrast to C_6H_5Cl the carbon-halogen frequency appears strongly in C_6H_5F. On the other hand, the vibration whose excitation brings the benzene spectrum into appearance and which shows up relatively intensely also in C_6H_5Cl, is of no prominence in the C_6H_5F spectrum. Bands appearing on the red side of the main bands with intervals of 67 and 206 cm^{-1} are considered as due to $v-v$ transitions of non-totally symmetrical vibrations. As in monochlorobenzene the structure of the spectrum becomes more complicated

toward the ultraviolet because of the increasing number of possible combinations of totally symmetrical vibrations.

52. Raman Spectra of Alkyl Acetylenes. FORREST F. CLEVELAND AND M. J. MURRAY, *Illinois Institute of Technology.*—Investigations directed toward a better understanding of the reasons for the occurrence of more lines for disubstituted than for monosubstituted acetylenes in the 2200 cm^{-1} region of the Raman spectrum have been extended to include 1-heptyne, 4-methoxy-1-butyne, 2-octyne, 3-octyne, 5-decyne, 7-tetradecyne and 9-octadecyne (all kindly supplied by Dr. G. F. Hennion of the University of Notre Dame). The monosubstituted acetylenes, 1-heptyne and 4-methoxy-1-butyne, gave only a single strong line at 2118 cm^{-1} and faint lines at 2064 and 2097 for the former, 2064 and 2094 for the latter. These weak lines may be attributed to the isotopic molecules, $R-C^{13}\equiv C^{12}-H$ and $R-C^{12}\equiv C^{13}-H$, respectively. The faint line at 2198 in the spectra of the disubstituted acetylenes may be ascribed to the isotopic molecule, $R-C^{13}\equiv C^{12}-R'$. If Fermi resonance is to account for the remainder of the lines, it seems probable that at least one fundamental in addition to the infra-red active $C-C\equiv C-C$ frequency (at 1126 in dimethylacetylene) must be involved. This may be an inner frequency (near 1100) of the $-CH_2$-group, since a line at 2245 is observed in the Raman spectrum of diethylacetylene in addition to the two strong lines near 2230 and 2300 which constitute the well-known resonance doublet of dimethylacetylene.

53. Absorption Spectrum of Monobromobenzene. I. WALERSTEIN, *Purdue University.*—The absorption spectrum of monobromobenzene in the region 2750–2400A was photographed with an E-1 spectrograph. An analysis of the bands shows that the spectrum is a combination of the allowed transitions due to the C_{2v} symmetry of C_6H_5Br and of the forbidden transitions of the benzene structure. The 0,0 band is located at 36.996 in the vapor and around 36,670 in the solid. Combinations of the totally symmetrical carbon vibrations of 933, 963, and 1020 cm^{-1} in the upper state account for one group of intense bands. This group also contains may bands spaced 60 (or 2×60) cm^{-1} away. This frequency difference is interpreted as the decrease in the upper state of the totally symmetrical ground vibration of 185 cm^{-1}. The excitation of an E_g^+ vibration which makes the forbidden transition of benzene partly allowed is evident in the C_6H_5Br spectrum by the presence of a second group of intense bands displaced 525 cm^{-1} from the first, This frequency corresponds to the nontotally symmetrical vibration of 616 in the ground state. Several of the Raman frequencies are observed in the weaker preposed bands. Further combinations occur with 242 and 2563 cm^{-1} corresponding to the totally symmetrical 317 and 3063 ground levels.

54. High Resolution Study of the Infra-Red Bands of Cyclopropane. LINCOLN G. SMITH, *Princeton University.*—At 3.3μ the fundamental bands of C_3H_6 due to C–H valence vibrations have been observed as follows: a perpendicular-type band at 3024.4 cm^{-1} whose fine structure was not resolved; and a parallel-type band with origin at 3103.0 cm^{-1} for which rotational structure has been measured. From these measurements the value 41.87×10^{-40} g cm^2 is obtained for the moment of inertia A'' in the ground state. From this, if one assumed C–H = 1.09A as in methane, one obtains values of the H–C–H angle from 126° to 146° for values of C–C between 1.52A and 1.54A. The most reasonable values appear to be C–H = 1.09A, C–C = 1.53A, H–C–H = 136°. The latter angle corresponds to a tetrahedral C–C–H angle. At 9.6μ a single perpendicular band has been found. The fine structure near the center of this band has been partially resolved, the average spacing of the pQ and rQ branches being 0.5 cm^{-1}. The origin of the band is at 1027.6 cm^{-1}. At 11.5μ there appear to be two bands very nearly coincident, the centers of each being within ±4 cm^{-1} of 870 cm^{-1}. Though the interpretation is not yet completely certain, it is practically certain that one of these bands is of the parallel type very similar to that at 3103 cm^{-1}. It thus appears that Linnett's[1] assignment of the low frequency fundamentals is incorrect. The correct assignment seems to be: The parallel band in the symmetry class A_2'' lies at about 872 cm^{-1} while the two degenerate perpendicular bands in the symmetry class E' lie at 1027.6 cm^{-1} and about 868 cm^{-1}. This assignment is in accord with the fact that Raman lines are observed at 1022 cm^{-1} and 863 cm^{-1} and with the selection rule that the E' vibration should appear in both Raman and infra-red spectra.

[1] J. W. Linnett, J. Chem. Phys. 6, 692 (1938).

55. Association of Alcohol Studied by Infra-Red Spectroscopy. H. S. SACK† AND J. PRIGOGINE, *University of Brussels.*—The association of alcohol molecules with alcohol molecules and with a series of other molecules is studied by the observation of the intensities of the infra-red absorption bands of binary and ternary solutions of alcohol at different temperatures. The results of these measurements may be represented by the law of Guldberg-Waage, and "association energies" can be calculated for the different complexes formed (e.g. ~5 kcal./mol. for double molecules). It is made probable that this association, often assigned to an O–H bond, is of electrostatic nature.

† Now at Cornell University.

56. On the Mechanism of the Nitrogen Afterglow. M. H. HEBB AND H. SPONER, *Duke University.*—The theory of active nitrogen proposed by Cario and Kaplan has been critically examined in the light of recent experimental and theoretical results. The theory is shown to be untebable since it requires transitions in violation of the Franck-Condon principle to be produced in collisions of the second kind. A new theory which is a modification of the old triple collision hypothesis is proposed. The energy of the afterglow (up to 5 hours) is stored partly as the energy of dissociation of the nitrogen into normal atoms and partly as the excitation energy of metastable ^2D atoms. A ^2D atom recombines with a normal atom in the presence of a third body directly into the $B^3\Pi$ state, which is the upper state of the afterglow bands.

57. Rotational Magnetic Moments of H_2, HD, and D_2. HARVEY BROOKS, *Harvard University.*—The formula for the rotational moment is, in atomic units

$$\mu=\frac{M_1+M_2}{2M_1M_2}M\left\{1-\frac{2}{R^2}\frac{\langle L^2\rangle_{Av}}{\langle E_{ON}\rangle_{Av}}\right\}J,$$

where M_1, M_2 are the nuclear masses, R the internuclear distance, $\langle L^2\rangle_{Av}$ the mean square electronic angular momentum, $\langle E_{ON}\rangle_{Av}$ a mean absorption frequency which we shall call the "downstairs centroid of angular momentum." Witmer has calculated the quantity $\langle L^2\rangle_{Av}$ with Coolidge-James functions, but no reliable theoretical estimate of $\langle E_{ON}\rangle_{Av}$ exists. However, it is possible to calculate an "upstairs centroid" for angular momentum, and both an "upstairs" and "downstairs" centroid for kinetic energy, and by taking the ratio of upstairs to downstairs centroids the same in both cases we obtained the value 1.97 atomic units for the downstairs centroid of angular momentum. With $\langle L^2\rangle_{Av}=0.222$ this gives a rotational moment of 0.885 nuclear magneton in good agreement with the measurements of Ramsey. With Witmer's value of 0.195 estimated with 11-term Coolidge-James functions, the calculated rotational moment is 0.91 nuclear magneton in less good agreement.

FRIDAY MORNING AT 9:30 O'CLOCK

National Bureau of Standards

Industrial Building

Session F—Crystal Structure and Allied Topics

58. Note on the Indexing of Powder Diffraction Patterns. LUDO K. FREVEL, *The Dow Chemical Company.* (*Introduced by J. D. Hanawalt.*)—Solutions for the quadratic form of Debye-Scherrer-Hull patterns have been limited in practice to cubic crystals and to the simpler substances with tetragonal or hexagonal symmetry. However, by supplementing the normal powder pattern by other physical data such as a temperature shift of the interference maxima,[1] it is possible to index more complicated cases. Another method of classifying the various reflections of a powder diagram is to produce a preferred alignment of crystallites in the specimen. An expedient technique for producing preferred orientation in a crystalline powder is to compound the powder with an amorphous plastic such as polystyrene and severly work the compounded material in its thermoplastic state. The fiber diagram obtained from the worked specimen can then be indexed by the standard methods applicable to complete rotation diagrams of single crystals. The method will be illustrated on the orthorhombic system.

[1] L. K. Frevel, Jr. App. Phys. **8**, 553 (1937).

59. X-Ray Structure Analysis of Polyvinyl Alcohol. ROSE C. L. MOONEY, *Newcomb College, Tulane University.*—The polymer is fibrous, showing good orientation about the fiber axis, and random orientation perpendicular to this direction. The experimental data consist of x-ray photographs taken with copper radiation filtered through nickel. There are about thirty measureable spots on the fiber diagram, which can be indexed with reference to a psuedo-orthorhombic cell of the following dimensions: $a=7.80$ A.U.; $b=2.52$ A.U.; $c=5.60$ A.U. The periodicity along the fiber axis, namely, 2.52 A.U., points to a planar zig-zag configuration for the carbon chain. There are two segments of $-CH_2CHOH-$ chains in the unit cell, giving a calculated density of 1.31. The reported value is 1.293. A study of the data leads to a structure having the symmetry of $C^2_{2h}-P2_1/m$. Positions have been found for the carbons and oxygens such that the calculated intensities are in good agreement with the limited number of observed intensities. The structure consists of long chain molecules so oriented that pairs of chains are linked through hydroxyl bonds between oxygens. The O−H−O distance is 2.7 A.U.

60. The Random Structure of Chrysotile Asbestos. B. E. WARREN AND K. W. HERING, *Massachusetts Institute of Technology.*—The present x-ray study of chrysotile indicates that a layer structure is in better agreement with the composition and the diffraction pattern than the previously proposed chain structure. The layers are built up in the sequence 3 O, 2 Si, 20 OH, 3 Mg, 3 OH. The diffraction pattern can be indexed in terms of monoclinic axes $a=7.33$A, $b=9.24$A, $c=5.33$A, $\beta=93°16'$. Nearly all reflections are of the type *hOl* or *Okl*. All *hOl* reflections are of the sharp crystalline type, most of the *Okl* reflections are smeared out along the layer lines resembling two-dimensional lattice reflections (*kl*). The diffuse reflections are due to a randomness in the stacking together of successive layers. The effects on the diffraction pattern of various kinds of randomness will be discussed.

61. Twinning in Nesquehonite, $MgCO_3\cdot 3H_2O$. R. PEPINSKY,* *University of Chicago.*—Earlier investigators[1] have assigned nesquehonite, $MgCO_3\cdot 3H_2O$, to the orthorhombic system, and from x-ray data Fenoglio[2] has placed it in space group $D_{2h}{}^1$–*Pmmm*, with $a=7.68$, $b=11.93$, $c=5.39$, and $Z=4$. Improbability of this space group prompted re-examination of the crystal, revealing that in terms of the orthorhombic cell *hkO* reflections are absent for $h+k$ odd, indicating a net plane parallel to (001) and

the space group D_{2h}^{12}–*Pmmn* or subgroup C_{2v}^{7}–*Pmn*. Despite optical data, certain systematic variations in diffracted intensities, and Patterson and Harker projections based on intensities, it was not possible to derive a structure in the orthorhombic cell. The failure is apparently associated with close doubling of many maxima on Laue, *a* and *c* axis oscillation diagrams, which persists in both natural and artificial crystals and suggests that the crystals are built of repeated twins of lower symmetry. This is in accord with conclusions of Cesaro,[3] based on cleavage properties and strongly-striped prism faces, and perhaps accounts for the doubled reflections from the basal plane reported by Penfield.[1] Further support is given the twinning hypothesis by observations of Rogers[4] on related hydromagnesite, $3MgCO_3 \cdot Mg(OH)_2 \cdot 3H_2O$, which is pseudo-orthorhombic due to polysynthetic twinning of monoclinic lamellae.

* Now at U. S. Rubber Co., Providence, Rhode Island.
[1] Genth and Penfield, Am. J. Sci. [3] **39**, 121 (1890).
[2] Fenoglio, Atti Acad. Lincei **24**, 219 (1936).
[3] Cesaro, Bull. Cl. d. Sc. Akad. Roy. Belgique (1910), 751.
[4] Rogers, Am. J. Sci. [5] **6**, 37 (1923).

62. The Structure of Stretched Rubber. C. M. PARSHALL AND K. LARK-HOROVITZ, *Purdue University.*—X-ray diffraction patterns of evaporated latex (sheets, 1.5, to 2.0 mm thick) at various elongations have been obtained and Fourier-analyzed. 100 percent, 200 percent, 250 percent stretching produces patterns similar in appearance to the pattern of the unstretched material; at 275 percent elongation crystal structure is definitely indicated. Three rings have been observed in the amorphous pattern at $\sin\theta$, values of 0.1047–0.1055; 0.210–0.220; 0.411–0.418. The half-breadth value of the first peak remains essentially the same for all elongations but its height and the appearance of the outer rings is changed. The distribution curves from the Fourier analyses show 1.9 first neighbors at 1.52A; 2.6–2.9 second neighbors at 2.48–2.54A. With increasing elongation the definition of the second peak increases and it appears completely resolved at 250 percent. A further concentration appears in all distribution curves at 5A; with increasing elongation concentrations at 3.5A and 4.2A, barely visible in the distribution curve of the unstretched latex, become strongly pronounced, comparable with the peak at 5A.

63. A New Electron Diffraction Camera for Molecular Structure Investigation. H. J. YEARIAN, *Purdue University.*—The electron diffraction method of molecular structure determination has a twofold limitation when applied to materials of low molecular weight. The total diffracted intensity is small since it is essentially proportional to the square of the molecular weight, and the useful diffraction pattern is one of low contrast superimposed on a very steep background. In the camera to be described, the over-all intensity has been raised by using electrostatic focusing to obtain 1–2-μa beams of 40-kv electrons. The second difficulty is reduced by incorporating a rotating sector in front of the plate which gives an exposure proportional to r^3, as introduced by P. P. Debye.[1] Check measurements with CCl_4 and N_2, and preliminary results on C_2H_2 will be given, together with a description of a simple mechanical device for calculation of the intensities to be expected from assumed molecular models.

[1] P. P. Debye, Physik. Zeits. **40**, 60 (1939).

64. The Structure of Black Carbon. ADDISON H. WHITE AND LESTER H. GERMER, *Bell Telephone Laboratories.*—Carbon films deposited upon silica surfaces by thermal decomposition of methane are of importance because of their microphonic properties. This paper is concerned with the results of determinations of the structure of more than 100 such films by means of electron diffraction, in some cases by the reflection method and in others by transmission through films after removal from their supports with hydrofluoric acid. In some of the specimens the individual crystallites are strongly oriented, and reflection patterns obtained from these are approximations to rotation patterns from single crystals. From these patterns one can conclude that the films consist of pseudo-crystals in each of which the carbon atoms are arranged in hexagonal planes as they are in graphite, but the successive parallel atomic layers are laterally displaced so that no regularities exist other than the uniform separation of the hexagonal planes and the regular arrangement of atoms in each of them. Determinations have been made of five structural parameters of the films,—average dimensions of crystallites parallel and normal to the planes of carbon atoms, mean separation of the planes and mean spacing in the planes, and degree of preferential orientation of the individual crystallites.

65. Crystal Structure and Surface Flow of Thin Evaporated Antimony Films. J. E. RUEDY, *RCA Manufacturing Co.*—When antimony is evaporated in vacuum onto a surface which is near room temperature, the resulting layer exhibits a flow phenomenon if the thickness is greater than a certain critical value, which is geometrically calculated on the basis of bulk density as geing about 85A. If the evaporation of the antimony is done quickly and then stopped, the coating on a flat glass plate at first has a normal continuous gradation of light transmission about the projection of the source. Within a few seconds, however, many pin points of greater opacity appear in the denser region and then grow and spread until they run together, finally forming a quite regular circular region of greater opacity with a sharp boundary. When studied by means of electron diffraction, the thicker type films yield sharp patterns which indicate the presence of well-developed crystallites with their 111 faces parallel to the base material, but otherwise randomly oriented. The thinner-type films give two diffuse rings which coincide with those due to reflections from the 110 and 221 planes, with no indication of orientation. The widths of these rings correspond to an average grating extension of about 10 atoms or 25A. Photographs of these films were taken with the electron microscope at a magnification of 13,000 diameters. Both types show a mosaic structure composed of irregular chains of about 150A in width, but with strikingly different density distributions.

66. Atomic Distributions in Liquid Aluminum and Lithium. CARL GAMERTSFELDER, *University of Missouri.*—The diffraction patterns of liquid aluminum and lithium have been obtained using Mo $K\alpha$ radiation, and the atomic distribution curves have been determined from them by means of a Fourier analysis. The diffraction pattern of aluminum at about 700°C has four maxima. In terms of $\sin\theta/\lambda$ units the first peak is at 0.10, the second peak, which is the most pronounced, is at 0.210, the third is at 0.36, and the fourth is at 0.55. The distribution curve shows that each atom in liquid aluminum has, on the average, 10.6 nearest neighbors at 2.96A. Each atom in crystalline aluminum has 12 nearest neighbors at 2.86A. The diffraction pattern for liquid lithium at 200°C has three maxima, located in terms of $\sin\theta/\lambda$ units, the first and strongest is at 0.195, the second at 0.340 and the third at 0.55. Each atom in liquid lithium has, on the average, 9.8 nearest neighbors at 3.24A. Each atom in the crystal has 8 nearest neighbors at 3.03A. In order to complete this analysis the density of liquid lithium had to be determined. The value of the density of liquid lithium at 195°C is 0.46 ± 0.01 g/cm^3.

67. Atomic Distribution Curve for Liquid Argon. C. N. WALL, *North Central College.*—Rushbrooke[1] has given a theoretical atomic distribution curve for liquid argon at 90°K based on Lennard-Jones and Devonshire's model ($N_1=12$, $R_1=4.077$A). His $4\pi r\rho_1(r)$ function for the first peak, obtained by numerical calculation, is compared with Wall's[2] simplified function. The two are found to agree closely when the parameter σ in the simplified function is chosen to make the maxima of the two functions coincide. This agreement is not accidental since σ can be calculated directly from the Lennard-Jones and Devonshire potential function for an argon atom in its cell and is found to be $0.140R_1$. This compares favorably with the value $0.141R_1$ given by Rushbrooke. Unfortunately, Rushbrooke's function does not agree with the experimental distribution curve for liquid argon given by Gingrich and Eisenstein.[3] A much better fit could be expected by choosing $N_1=7$ and $R_1=3.86$A. In this case the calculated value of σ is 0.48A whereas the value obtained from the experimental curve is 0.50A. These latter values of σ give satisfactory results for the entropy of liquid argon.

[1] G. S. Rushbrooke, Proc. Roy. Soc. Edinburgh **60**, 182 (1940).
[2] C. N. Wall, Phys. Rev. **54**, 1062 (1938).
[3] A. Eisenstein and N. S. Gingrich, Phys. Rev. **58**, 307 (1940).

68. Structure of Liquid Helium. L. I. SCHIFF, *University of Pennsylvania.*—The weak forces that exist between helium atoms and the large zero-point kinetic energy of their motion in liquid helium make the usual theory of liquids inapplicable to this substance. However, x-ray data indicate the regular distribution of nearest neighbors that is characteristic of normal liquids. From the point of view of the one-particle model, this suggests that at moderate temperatures each atom moves throughout the whole volume in the approximately periodic field of the other atoms, this periodic field being produced by correlations between positions of the atoms. At absolute zero we assume that each atom is in a semi-bound state in the field of its neighbors, in which it may diffract over several atom distances; while there may be one such state for each atom, the large zero-point energy and weak forces preclude the existence of more than one. The phase transition then consists of the "condensation" of atoms from excited gas-like states to the lowest liquid-like states. The resulting specific heat curve resembles, but is less steep, than that found experimentally. Arguments will be presented that indicate that the liquid-like states contribute a negligible amount to the viscosity.

69. On the λ Transition in Liquid Helium. W. E. LAMB, JR. AND A. NORDSIECK, *Columbia University.*—In the previous attempts to relate the transition between liquid helium I and II to the condensation of a Bose-Einstein gas, one has not been able to obtain a discontinuity of the specific heat curve at the transition temperature, without *ad hoc* assumptions about the distribution of energy levels for the motion of single atoms. We have obtained an expression for the energy levels of the system as a function of the numbers N_i of atoms in the various states, which is strictly valid only for low densities, i.e., in the uncondensed gas. The calculation is similar to that of the correlation energy in the theory of metallic binding, except that use is made of the fact that the range of the forces is small compared to the wave-length. The energy contains quadratic terms in N_i as well as the usual $\Sigma_i N_i E_i$. If there is no bound level in the intermolecular potential, the quadratic terms favor condensation. We have calculated the partition function with the above energy expression and find, apart from a latent heat, a specific heat curve of the observed form.

FRIDAY MORNING AT 9:30 O'CLOCK

National Bureau of Standards

Chemistry Building

Session G—Fundamental Theory and Diverse Topics

70. Finite Electromagnetic Self-Energies and Nuclear Electric Forces. ALFRED LANDE, *Ohio State University.*—When monochromatic radiation is scattered by an electric particle, a pulsating energy amount is retained by the particle according to the classical theory. For very high frequencies this energy is reduced in its amplitude and

retarded in its phase. The "mutual energy" in Dirac-Fermi's radiation theory is just this pulsating energy, without the reduction for high frequencies, however, thereby leading to infinite self-energies. Correcting this deficiency we arrive at a "cutting-off method" made invariant by the Doppler effect for particles in motion through the radiation field. The electromagnetic self-energy becomes $\frac{3}{4}$ of mc^2, if m is the total inertia, leaving the possibility of neutral particles having a rest mass, too. The Coulomb potential changes to $(e^2/r)[1-\exp(-r/r_0)]$ where $r_0=2e^2/3mc^2$, for particles of equal masses. A more complicated formula with applications to nuclear physics results for the potential between masses m and M. Whereas the potential of one charge on another of equal mass remains finite even for $r=0$, the potential on a test charge $M=\infty$ becomes infinite for $r=0$, similar to the distinction between E and D in Born-Infeld's theory. For an electron and a proton at the distance $r=0$ the mass defect is only a few electronic mass units. For electrostatic reasons alone, electrons and positrons could exist as such inside the nucleus. The appearance of an electromagnetic "radius" is the result of radiation damping, rather than of any change of the basic field equations as proposed by the unitary theories.

71. The Gravitational Field in Special Relativity. N. ROSEN, *Black Mountain College.*—Although previous attempts to describe gravitation in the special theory of relativity have not been successful, one can do this satisfactorily provided one uses for the potential of the gravitational field a symmetrical tensor of rank two. However, if such a description is used, it turns out that reasonable assumptions lead to field equations and equations of motion which are formally the same as the ones in the general theory of relativity.

72. On Relativistic Thermodynamics. PETER G. BERGMANN, *Institute for Advanced Study.*—A relativistic treatment of thermodynamics has been proposed by several authors[1] and lately by Eckart[2] for a continuous medium. The entropy of a system is an invariant, as shown by a statistical or a purely thermodynamical argument. The temperature has to be replaced by a world vector, β_ρ. Its scalar product by the four-velocity is equal to $1/T_0$ (T_0 being the proper temperature), while its fourth component is $1/T$ (T being the relativistic temperature). Contrary to the usual assumption, β_ρ need not be $1/T_0$ times the four-velocity of the system, particularly when the "system" is an infinitesimal amount of matter in a fluid. Eckart's resolution of the energy-momentum tensor into proper components and his formulation of the first and the second laws will be discussed.

[1] A. Einstein, *Jahrbuch der Radioaktivität und Elektronik* (1907), Vol. 4, p. 411; M. Planck, Berl. Ber. p. 542 (1907); Ann. d. Physik **26**, 1 (1908); Van Dantzig, Physica **6**, 673 (1939).
[2] C. Eckart, Phys. Rev. **58**, 919 (1940).

73. Theory of Superconductivity. J. BARDEEN, *University of Minnesota.*—It is assumed that in the superconducting state there is a small periodic distortion of the lattice yielding a unit cell containing $\sim 10^6$ atoms. This gives rise to a fine grained zone structure in k space. Electrons which have energies within $\sim kT_c$ of the energy surface lie near the boundaries of $\sim 10^4$ zones and some of these have a very small effective mass ($\sim 10^{-4}m$). A small fraction of the electrons have a very high diamagnetic effect, sufficient to make the metal a perfect diamagnetic. Although about one electron in 10^4 lies in the surface zones, only about one in 10^6 is a superconducting electron. The energy discontinuities produced by the zone structure yield a decrease in the energy of the electrons at the expense of the increase in energy of the lattice resulting from the distortion. A rough estimate of the interaction between the electrons and the lattice obtained from the electrical conductivity in the normal state indicates that the superconducting state may be stable at low temperatures. The most favorable metals are those which have a high density of valence electrons in a wide energy band and which have a large interaction between electrons and lattice (low conductivity).

74. Attractive Forces Between Ions and Neutral Molecules. H. MARGENAU, *Yale University.*—In theories of ionic mobility the attractive potential between an ion and a neutral molecule is usually taken to be $\frac{1}{2}e^2\alpha R^{-4}$, α being the polarizability of the molecule and R the internuclear distance. This represents only the long range attraction. At closer range, terms proportional to R^{-6} appear. The present note examines their magnitude. They are due to two causes: (a) the inhomogeneity of the ion field; (b) mutual polarization of the two structures (dispersion forces). The latter are well known. The former yields a contribution approximately given by $(e^4/5R^6)\langle r^4\rangle_{00}$, where $\langle r^4\rangle_{00}$ is the fourth moment of the charge distribution of the neutral molecule. When computed for He, this term adds about 5 percent to the usual attraction at minimum separation between ion and atom. Estimates of the term have been made for molecules satisfying a one-term dispersion formula. It is generally small enough to be neglected in cruder theories of mobility, but should be included in quantitative considerations. Cause (b) contributes a somewhat larger attraction; both causes may increase the attraction by about 30 or 40 percent at closest separation. A list of computed values of the terms proportional to R^{-6} for different gases will be presented.

75. Action at a Distance between Simple Atoms. JOHN A. WHEELER, *Princeton University.*—The mutual energy of two atoms in S states varies in a complicated way for small internuclear separations but for larger distances approaches van der Waals' $1/r^6$ law. In quantum mechanics this result receives a simple interpretation. The instantaneous energy of interaction of two dipoles varies as $1/r^3$; the dipole moments of the two atoms vanish, however, in the first approximation; and the second approximation leads to van der Waals' law. At distances outside the so-called wave zone of the oscillating dipoles, however, the field falls off more slowly than $1/r^3$. Consequently, van der Waals' force assumes a dependence upon distance different from $1/r^6$ for separations greater than the wave-length associated with the resonance radiation of the atoms in question.

76. The Energy of Dissociation of Water Vapor. ROBERT J. DWYER,* *Harvard University.*—A precise determination of the energy of dissociation of water vapor in the reaction $H+OH=H_2O$ was undertaken following the method of Bonhoeffer and Reichardt.[1] This consists essentially in applying the integrated form of the van't Hoff isochore to the measurement of the heat of reaction for $H_2O+O_2=4OH$ by observing the OH absorption spectrum under different conditions of temperature and oxygen-water vapor mixture. This heat of reaction, when reduced to absolute zero and combined with two accurately known reaction energies, gives the dissociation energy of H_2O into H and OH. The uncertainty introduced into the work of Bonhoeffer and Reichardt by their failure to resolve the individual lines of the absorption spectrum was avoided by the use of the second order of a 21-foot grating. The oven temperature was controlled automatically to a fraction of a degree, and the temperature distribution was measured by a platinum, platinum-rhodium thermocouple which could be adjusted to different positions along the length of the oven. The principal result was

$$H+OH=H_2O-117.6\pm0.5 \text{ kilo-calories.}$$

* Charles A. Coffin Foundation Research Fellow.
[1] K. F. Bonhoeffer and H. Reichardt, Zeits. f. physik. Chemie **A139**, 75 (1928).

77. Electron Microscopical Determination of Object Thickness. L. MARTON, *Collingswood, New Jersey.*—The usual methods of light optics for measuring the thickness of a specimen cannot be applied in electron microscopy. In case of thin objects, however, the measured intensity distribution of the micrographs permits the calculation of the thickness in first approximation. The first of several necessary assumptions is that only single scattering occurs. The classical Rutherford formula is applied for obtaining numerical values. The results are represented in the form of a nomogram with aperture ratio of the microscope, electron speed, blackening of the micrograph, and mass thickness of the object as variables. The limitations of the method are indicated and a few practical examples given.

78. A Magnetic Electron Microscope. G. G. HARVEY AND L. J. SULLIVAN, *Massachusetts Institute of Technology.*—A two-stage high magnification magnetic electron microscope has been constructed. A flexible design has been adhered to throughout so that the instrument may be easily disassembled for modification of the lens properties. An object stage similar to that of Ruska permits changing of specimens without breaking the vacuum. Provision is made for transverse and vertical adjustment of the object as well as a means of tilting the object for the purpose of taking stereoscopic pictures. The camera is provided with air-locks and external controls so that the plates may be changed without breaking the vacuum; several exposures may be made on the same plate. The pole piece design of the objective and the projection lens permits of ready removal and substitution of different shapes. The requirement of complete axial symmetry in these pole pieces is met by using the Prebus one-piece type of construction. Adjustments are provided in each of these lenses to bring the aperture into coincidence with the axis of the field. The condensing lens is fitted with apertures and stops of various sizes, providing for both bright and dark field illumination.

79. The Apsidal Motion in Binary Stars for a Point Source Convective Core Model with Varying Guillotine Factor. LLOYD MOTZ, *The College of the City of New York and Columbia University.*—Since investigations of the energy source in stars depend upon a definite stellar model, it is important to obtain independent verification of the density distribution yielded by such a model. The equation[1] which gives the distortion of components of a binary system was integrated numerically[2] for the second and third harmonics, using the values of the density and mass distributions for a polytrope of index 1.5 inside the convective core and the values given by "The project for the computation of mathematical tables"[3] for a point-convective solar model in the external region. The ratio of the orbital to the apsidal period is given as an expansion in k_2, k_3, etc., which are related to the harmonics. For the point-convective model k_2 and k_3 are 0.00616 and 0.00155 respectively. These values are to be compared with the values 0.0144 and 0.00368 for a polytrope of index 3 and 0.00134 and 0.00024 for a polytrope of index 4. For the binaries for which observations are available,[1] the observed apsidal motion corresponds to polytropes with indices between 3 and 4 and is therefore in qualitative agreement with the point-convective model.

[1] T. E. Sterne, M.N.R.A.S. **99**, 451 (1939); **99**, 662 (1939).
[2] Most of the numerical work was done by the Astronomical Computing Bureau at Columbia University.
[3] H. A. Bethe, G. Blanch, A. N. Lowan and R. E. Marshak, Phys. Rev. **59**, 467 (1941).

80. Formation of Multiple Stars by Fission and Simultaneous Capture. ROSS GUNN, *U. S. Naval Research Laboratory.*—The zone of gravitational instability surrounding a star is found to extend indefinitely as the rotational velocity of a visiting star approaches its critical fission value. Further, fission may occur at angular velocities notably below the critical value if the approach of two stars is close. Thus rapidly rotating stars divide by fission, preferentially in the vicinity of another star. In a close approach some orbital energy is used to separate the components of the visiting star and to change its axial rotation by tidal action. Upon determining graphically the orbits of the resulting three bodies it is found that various natural initial conditions permit: (a) the passage of the stars without effect, (b) the simple fission of either star producing either a close or a moderately separated pair, (c) the fission of one star, one component returning to infinity and the other being captured, (d) the fission of one star with the capture of both components by the other, usually forming a spectroscopic pair accompanied by a remote companion. These are in agreement with observed multiple star systems. However, because present data suggest that the close approach of two stars is not common it seems necessary to conclude that most binary systems evolve from *single* stars, probably in a manner much like that described in the author's "binary star fission theory" of the origin of the solar system.[1]

[1] R. Gunn, Phys. Rev. **39**, 130, 311 (1932).

FRIDAY MORNING AT 9:30 O'CLOCK

National Bureau of Standards

East Building

Session H—Cosmic Rays

81. The Lateral Extension of Cosmic-Ray Showers. L. W. NORDHEIM, *Duke University.*—The problem of angular scattering and lateral extension of showers can be solved completely if their longitudinal extension is known, i.e., the function $f(E_0, E, x)$ giving the number of electrons of energy E produced at the distance x by a primary E_0. For energies above the ionization limit the mean square deviation of electrons or quanta can be expressed by a rapidly convergent series showing the contributions of parent quanta, grandparent electrons and so on. For low energies a good approximation can be obtained by decomposing the electron distribution into two parts, the electrons which have been slowed down from high energies and those which have been created with low energies by quanta. The theoretical spread is much larger than estimated by Euler and Wergeland. It is fully sufficient, for instance, to explain the observations by Auger on large air showers, our value for the root mean square deviation being ~90 meters in agreement with a figure given by Bethe.[1]

[1] H. A. Bethe, Bull. Am. Phys. Soc. **16**, 7 (1941).

82. On the Theory of Cosmic-Ray Showers Including Ionization Loss. BRUNO ROSSI, *Cornell University.*—It is known that, neglecting ionization, the energy distribution of shower electrons at a thickness t and in the neighborhood of the energy E can be approximated by a power spectrum const $\times dE/E^{s+1}$. s is a function of the ratio $t/\ln(E_0/E)$, where E_0 is the primary energy. It is shown that, if the ionization loss is taken into account, the expression of the energy spectrum becomes const $\times dE/(E\eta)^{s+1}$. η is a function of s and ϵ/E (ϵ being the ionization loss per radiation unit) which can be conveniently calculated in the form of a series $\eta = 1 + a_1(s)(\epsilon/E) + a_2(s)(\epsilon/E)^2 + \cdots$ for energies in the neighborhood of ϵ.

83. A Cosmic-Ray Radio-Sonde. H. V. NEHER AND W. H. PICKERING, *California Institute of Technology.*—The cosmic-ray radio-sonde described in this paper was used for observations in the stratosphere near the magnetic equator. The instrument can be used for single counters or coincidences up to fourfold. It includes the necessary amplifiers and scaling circuits to operate a relay which keys the radio-transmitter. High voltage for the counters is provided by a buzzer and transformer unit. Small storage batteries are used for power to operate the unit for about three hours. Pressure and temperature signals are sent at eight-minute intervals. The complete instrument ready for flight weighs about 3300 grams. The receiving equipment consists of a super-regenerative receiver with the signal output recorded on a paper tape.

84. Results of a High Altitude Cosmic-Ray Survey Near the Magnetic Equator. W. H. PICKERING AND H. V. NEHER, *California Institute of Technology.*—Electroscope and Geiger counter observations have been taken with free balloons at geomagnetic latitudes of 3°, 17°, and 25°N. The most important results are as follows: (1) The Geiger counter technique using a single counter will give results very close to those obtained with the electroscope and of comparable accuracy. (2) Vertical coincidence measurements give rise to markedly different values for the relative amounts of incident energy at various latitudes, as compared with the electroscope or single counter data. (3) Within the experimental error, no difference was obtained between the vertical coincidence curves at 3° and 17°, and thus no new energy lies in the primary energy spectrum between the limits of 17 and 14 Bev. (4) This is direct evidence for a banded structure in the primary cosmic-ray spectrum. (5) Flights made with triple and quadruple coincidences, and also with counters arranged to record showers, showed that showers do not significantly affect the vertical coincidence measurements.

85. The Experimental Testing of a Hypothetical Distribution of Energy in the Cosmic-Ray Spectrum. ROBERT A. MILLIKAN, *California Institute of Technology.*—From a previously reported theory of the origin of cosmic rays it is possible to predict the existence of definite cosmic-ray bands and plateaus of unchanging cosmic-ray intensities as a function of latitude. In this paper these predictions are compared with already existing data and it is shown from them why the recent exploratory work in India was done at the chosen latitudes, the results of which are reported in the accompanying papers by Neher and Pickering.

86. The Vertical Intensity and the Latitude Effect of the Hard Component at High Altitudes. WILLIAM P. JESSE, E. O. WOLLAN AND MARCEL SCHEIN, *University of Chicago.*—Further measurements[1] of the intensity of the hard component have been carried out up to altitudes corresponding to about 3 cm Hg both at Chicago ($\lambda = 51°$N) and at Waco, Texas ($\lambda = 40°$N). The vertical intensity for various lead thicknesses between the counters increases continuously up to the highest altitudes reached (1.8 cm). The value at this point at Chicago is about 13 times that at sea level. At 3-cm pressure the latitude effect for the hard component between 51° and 40° was found to be about 15 percent for lead thicknesses of 8 and 10 cm. No maximum in the intensity curves was observed in any of these later experiments.

[1] Marcel Schein, William P. Jesse and E. O. Wollan, Phys. Rev. **57** 847 (1940).

87. The Production of Mesotrons by Ionizing Cosmic Rays. MARCEL SCHEIN, WILLIAM P. JESSE AND E. O. WOLLAN, *University of Chicago.*—An experiment designed to investigate the possibility that ionizing particles may produce mesotrons has been carried out at high altitudes. Four fourfold coincidence counter sets were used. Two of these sets, each covering the solid angle of the other, were used to measure the vertical intensity through 18 cm of lead. A third counter set was arranged to measure below the total lead the emergence of one or more particles accompanying a particle traversing the set. The fourth counter set similarly registered the ejection in the first four centimeters of lead of two or more particles coincident with the traversing particle. At altitudes corresponding to a pressure of 3 cm Hg 46 percent of the vertical coincidences registered in set 1 and 2 were accompanied by coincidences in set 3 and 15 percent were accompanied by coincidences in set 4. The fact that set 4 records only 15 percent of the vertical particles indicates that at least 85 percent of the mesotrons at 3 cm pressure are not produced by the soft component. The large proportion of counts (46 percent) recorded by set 3 seems best explained by assuming that one traversing ionizing particle which is probably a proton produces a number of mesotrons in the lead.

88. The Nature of the Primary Cosmic Radiation. E. O. WOLLAN, MARCEL SCHEIN AND WILLIAM P. JESSE, *University of Chicago.*—Seven balloon flights with counter arrangements similar to those used before have been made with lead between the counters of thickness 4, 6, 8, 10, 12 and 18 cm. The vertical intensity *vs.* altitude curves were found to be nearly the same for all of these thicknesses at the highest altitudes reached (less than 1 radiation unit from the top of the atmosphere). This fact is not in agreement with the assumption that electrons between 10^9 and 10^{12} ev enter the earth's atmosphere. Further evidence as to the nature of the particles was obtained by side counters arranged to register any showers which accompany a particle traversing the apparatus. The number of counts in the side counters was in no case more than a few percent of the number of traversing particles. Within one radiation unit of the top of the atmosphere a large proportion of the particles entering the apparatus should be of primary origin. Since electrons ($10^9 < E < 10^{12}$ ev) are not observed at these altitudes they must constitute at most a very small fraction of the primary radiation. The incoming radiation, according to our experiments, must be ionizing, penetrating and non-shower-producing and hence consists probably of protons.

89. The Effect of External Temperature on Cosmic-Ray Intensity. NIEL F. BEARDSLEY, *University of Chicago.*—A considerable diversity of opinion seems to exist as to the importance and magnitude, even of the sign, of the effect of external temperature on the ionization due to cosmic rays as observed at the surface of the earth. A study of cosmic-ray intensities, the temperatures and the pressures at Cheltenham indicates that the difference in the results of different observers is caused by different methods of computation. Using each available day for one year (A); the average result of using monthly periods (B); and the results of using the monthly averages of the variables (C); (δP in millibars, δT in degrees C, δI in percent of variation from the annual mean)

(A) $$\delta I = -0.161\delta P - 0.132\delta T$$

Contribution to the variance of I;

P : 27 percent T : 33 percent

(B) $$\delta I = -0.134\delta P - 0.065\delta T$$

P : 56 percent T : 3 percent

(C) $$\delta I = -0.205\delta P - 0.154\delta T$$

P : 0 percent T : 69 percent

indicate that daily changes in temperature are, as some have reported, not important; however the seasonal changes in temperature are extremely important. Other correlation results will also be discussed.

90. Cloud Chamber and Counter Tube Cosmic-Ray Studies Under Ground. DONALD J. HUGHES AND VOLNEY C. WILSON, *University of Chicago.*—At the Cosmic-Ray Symposium held at Chicago in June, 1939, it became evident that several different types of cosmic rays may be present below ground. To identify some of these rays, the following experiments were performed in the Isle Royal Copper Mine at Houghton, Michigan. An eight-inch cloud chamber in a 1230 oersted magnetic field was set up at a depth of 70 meters water equivalent. Abundant evidence is present for penetrating ionizing rays accompanied by secondary negative electrons. A few large showers were observed. Attempts to detect secondaries produced by penetrating non-ionizing rays gave negative results. Counter tube absorption experiments were performed at 70 meters and 630 meters. Within the experimental errors, the relative number of soft secondaries to the penetrating rays is the same at the two depths. At various depths counter tube measurements were made of showers produced in a 15-cm lead block. At moderate depths, but not at the greater depths, there is some evidence that a small percent of the showers are produced by non-ionizing rays. The relative number of large showers increases greatly with depth. These experiments indicate that the large majority of the penetrating rays underground are ionizing, probably mesotrons and/or protons.

91. The Latitude Effects of the Hard and Soft Components of Cosmic Rays. V. C. WILSON AND R. N. TURNER, *University of Chicago and Canadian-Australasian Line.*—Two threefold Geiger-Mueller tube telescopes were mounted upon the *R.M.M.S. Aorangi*, which plies between Vancouver, Canada, and Sydney, Australia. The telescopes subtended identical solid angles. One recorded both the soft and the hard cosmic rays, whereas the other, which contained 11 cm of lead as an absorber, recorded only the hard rays. The difference between the two counting rates represents the intensity of the soft rays. Data were taken during four round trips. The latitude effect for the soft rays is slightly greater than for the hard rays. If the soft

component is produced by the hard component, one should expect the latitude effect of the soft rays at sea level to equal that of the hard rays at the altitude where the hard rays produce the observed soft rays. At an altitude above sea level the latitude effect of the hard rays is greater than at sea level; so, also, the latitude effect for the soft rays at sea level should be slightly greater than for the hard rays at sea level. Since this agrees with the observations, one may conclude that the soft cosmic rays at sea level are secondaries produced by the penetrating rays.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

National Bureau of Standards

East Building

Session I—Cosmic Rays, Geiger Counters, Diverse Topics

92. Further Experiments on Mesotron Showers. W. F. G. SWANN AND W. E. RAMSEY, *Bartol Research Foundation of the Franklin Institute.*—A quintuple coincidence set of Geiger counter sensitive areas, with a large thickness of metal below the upper area, was used as in the case of observations formerly reported. The block of metal was of tin and each of the four lower trays was covered with a slab of lead 1 cm thick. 11,000 "events," corresponding to the passage of at least one ray through the whole apparatus, gave two cases in which one counter discharged in the upper tray and two counters discharged in each of the four lower trays, and thirteen cases in which two counters discharged in the upper tray and two discharged in each of the lower trays. The absence of multiplicative effects arising in the lead slab suggests that the pairs in each case were mesotron pairs. The characteristics of the apparatus are such that the thirteen observations above referred to represent 12,000 times the value which would be calculated from accidental coincidences of the individual counters conspiring to produce these events, and 2600 times the number which would be obtained by the accidental passage of two mesotrons through the apparatus within its resolving time. The directions of the rays as defined by the geometry of the counters is in harmony with the supposition of mesotron pairs.

93. Rest Mass and Lifetime of the Mesotron as Found from Cosmic-Ray Measurements. PAUL WEISZ, *Bartol Research Foundation of the Franklin Institute.*—The values for the lifetime of the cosmic-ray mesotron obtained experimentally by various authors show considerable disagreement even after recalculation on the basis of equivalent conditions. However, these values show a marked relation to the average path length of the radiation in each experiment. Since experimental determinations of the mesotron rest mass have yielded values from below 100 to over 500 times the electronic mass, a distribution in rest masses is assumed rather than a single rest mass, and with this postulate it is shown that a relation between measured "pseudo-lifetime" and path length must be expected of the sort actually found regardless what form the distribution may possess. The deviation of the pseudo from the real lifetime becomes smaller with decreasing path length. An extrapolation towards zero path length leads to a real lifetime of the order of 5×10^{-7} sec. consistent with Yukawa's original prediction. Other experimental findings, as the increasing frequency of heavily ionizing tracks with altitude, the secondary peak of the Rossi curve, and possibly others may also be explained on the basis of a distribution in rest mass.

94. Multiple Values of the Specific Ionization Produced by Cosmic-Ray Entities. W. E. RAMSEY, W. F. G. SWANN, AND PAUL WEISZ, *Bartol Research Foundation of the Franklin Institute.*—Some years ago two of us reported measurements of the ionization per centimeter of path in argon, and we recorded two primary values, one about double the other. The experiments have now been repeated with improved resolving time, using a proportional counter system in place of the ionization chamber formerly used. Again the results indicate two primary values for the ionization, occurring with comparable frequency, and multiple values occurring with much smaller frequency and corresponding to each of these primary values. The proportional counter was operated by the assistance of other ordinary Geiger counters in such a manner as to define a unique path length within the proportional counter itself. The procedure of measurement involved a collection of charge corresponding to the ionization along the fixed path length, and the time of collection was of the order of 10^{-4} second. The control counter system also limited the sensitive time of the apparatus to 10^{-4} second, and the net result was that in the measurements there was only one chance in a thousand of more than one ray participating in the charge measured in any particular case, unless more than one ray participates as part of a simultaneous multiple event.

95. The Initial Avalanche in Discharge Counter Breakdown. SANBORN C. BROWN AND W. P. ALLIS, *Massachusetts Institute of Technology.*—A theoretical study of the initial avalanche in discharge counter breakdown has been undertaken. In the most general case three regions exist within the counter: (1) the region in which no multiplica-

tion takes place, (2) the region in which the avalanche multiples, (3) the region in which the multiplication is reduced by the space charge of the avalanche. Graphical integration of the multiplication as a function of the position in the counter shows that the form of the function is quite independent of the particular space charge model assumed. In region 2 the field is inversely proportional to the distance from the anode and the total number of ions produced can be computed from a single function. This function has been tested experimentally for helium and found to be valid over the pressure range from 5 mm to 7 atmospheres and a ratio of cathode to anode radii from 250 to 1.4. In region 3 the assumption that the ionization is constant can be shown to be satisfactory and the total multiplication can again be computed from a single function. The relation of these functions to the counter breakdown voltage is discussed.

96. Time Lags in Geiger-Müller Counter Discharges. C. G. MONTGOMERY AND D. D. MONTGOMERY, *Yale University.*—A spark produced simultaneously a burst of ultraviolet light and an electrical pulse. The ultraviolet light ejected photoelectrons from a counter cathode and started a discharge. The electrical pulse was delayed a known time by a vacuum-tube circuit which was also energized by the pulse from the counter wire. The number of counts from the counter and the number with lags greater than a given time were recorded. Knowing the average number of photoelectrons formed by a burst of photons, the probability that an electron would be captured to form a negative molecular ion could be determined. In a counter, 18 mm in diameter, filled with a mixture of argon with 6 percent oxygen, the probability of capture in such a way as to produce a lag of more than 1.4 microseconds increased with pressure, attaining a value of 1.48 at 19 cm of mercury. From the known breakdown characteristics of argon-oxygen counters, the mean cross section for capture by an oxygen atom was found to be about 10^{-18} cm^2 in agreement with previous measurements. In a counter in which the primary ions are produced in the gas, the fraction of delayed counts at first increases with pressure, reaches a maximum, and falls again at higher pressures.

97. A Precision Method of Measuring Geiger Counter Resolving Times. YARDLEY BEERS, *New York University.*—An improved method for measuring resolving times of Geiger counters has been devised for use in some recent work on the measurement of the charge of the β-particle.[1] The counting rates of two constant β-ray sources, first separately and then together, are measured. Because of the finite resolving time the sum of the counting rates due to the separate sources exceeds that due to the combined source. By application of formulae which have been derived the resolving time and error involved are calculated from these quantities. Relatively high accuracy can be obtained without excessive expenditure of time upon the measurements and without the use of high counting rates for which the validity of correction formulae is questionable or which damage the counter. For example, for a determination of a resolving time of about 10^{-4} second lasting one hour, the probable error in the corrected counting rate at 300 counts per second is only one half of a percent.

* This work was done at Princeton University, Princeton, New Jersey.

[1] R. Ladenburg and Y. Beers, Phys. Rev. **58**, 757 (1940).

98. Forms of Discharge in Micro-Gaps. R. W. JONES, *Central Y.M.C.A. College,* AND W. S. HUXFORD, *Northwestern University.*—Hobbs[1] and others have shown that significant departures from Paschen's law occur in the low voltage spark breakdown across gaps of the order of 10^{-4} cm at atmospheric pressure. More recently Pearson[2] has measured the field currents prior to breakdown. In the present report it is shown that transient discharges occur between polished silver electrodes at atmospheric pressure before arcing sets in. These discharges are faintly audible and luminous when observed in a darkened room. They produce markings of the electrode surfaces which are different from those formed in the usual spark discharge. Four types of patterns are noted: (1) A "bird-shot" pattern of small spots clustered in an irregular manner about a central circular area devoid of spots; (2) Multicolored rings enclosing a clear central area; (3) Rings as in (2) in which the central area contains a "bird-shot" pattern; (4) Circular patterns similar to (2) except that the colored rings completely fill the area. Cathodes and anodes exhibit differences which are consistent in all types of markings. Evidence is found that these discharges are initiated by field electrons as previously observed in reignition of arcs across switch contacts.[3]

[1] G. M. Hobbs, Phil. Mag. [6] **10**, 617 (1905).
[2] G. L. Pearson, Phys. Rev. **56**, 471 (1939).
[3] W. S. Huxford, S. G. Eskin and R. W. Jones, Phys. Rev. **55**, 1146(A) (1939).

99. The Colinear Emission of Annihilation Quanta. ROBERT BERINGER AND C. G. MONTGOMERY, *Yale University.*—The distribution in angle between the two oppositely directed quanta resulting from the annihilation of a Cu^{64} positron has been studied with coincidence counters. Two counters were placed at equal distances on opposite sides of a small pellet of activated copper foil wrapped in lead foil slightly thicker than the positron range, each counter subtending 0.0133 steradian. The ratio of the number of coincidences to the number of counts in a single counter was determined for various displacements of one counter from the position in line with the source and second counter. For the in-line position, this ratio represents the efficiency of one counter for 0.51 Mev photons and was about 10^{-3}, in agreement with the accepted value for similar counters. The observed variation of this ratio with displacement agreed closely with that calculated from the geometry for quanta emitted in exactly opposite directions. The results indicated that the two quanta are oppositely directed to within one degree.

100. Measurement of the Electron-Electron Cross Section at Energies from 1.3 to 2.6 Mev. PAUL E. SHEARIN AND T. EUGENE PARDUE, *University of North Carolina.*—Until recently experimental values of the electron-electron

cross section covered a restricted range of energies. The results of some experimenters disagree with Möller's relativistic theory. The situation was clarified by Howell and Hornbeck (Proc. Am. Phil. Soc.) who measured 190 meters of track in nitrogen (primary energy, 1.3–2.6 Mev), finding 107 secondaries with energies greater than 20 Kev. This investigation extends their work, with objects of increasing the accuracy of measurement and decreasing statistical error. We employed 343 meters of track. Letting R equal observed cross section over calculated cross section, the results were these:

Observer	Lower Limit of Secondary Energy	Number of Secondaries	R
H. and H.	20 Kev	107	1.21 ±0.12
	30	63	1.12 ±0.14
	40	35	0.86 ±0.15
S. and P.	20	180	1.11 ±0.07
	30	105	1.02 ±0.10
	40	81	1.07 ±0.11

101. The Growth of Drops in a Wilson Cloud Chamber. Wayne E. Hazen, *University of California.* (*Introduced by Robert B. Brode.*)—The rate of growth of ethyl alcohol drops in nitrogen, helium, and hydrogen was measured by photographing the drops in a cloud chamber with intermittent illumination of known frequency. Measurements of the separations of successive images on the film gave data for calculating the velocity as a function of time and hence, from Stokes' law, the radius as a function of time. The square of the radius increased linearly with the time in all cases, the slopes being about 6×10^{-6} cm²/sec. for nitrogen and 18×10^{-6} cm²/sec. for hydrogen. The rate of growth was found to increase linearly with expansion ratio from the ion threshold to the fog threshold. The temperature of the drop was calculated from the rate of growth. From the drop temperature and its rate of growth and the vapor pressure of ethyl alcohol as a function of temperature the diffusion coefficients for ethyl alcohol vapor in nitrogen, helium and hydrogen were calculated. Reasonable agreement with other measured values of the diffusion coefficients was obtained.

Friday Afternoon at 2:00 o'clock

National Bureau of Standards

Chemistry Building

Session J—X-Rays; Sound; Diverse Topics

102. The K-Absorption Edges of Metal Ions in Solution. W. W. Beeman* and J. A. Bearden, *The Johns Hopkins University.*—A double crystal spectrometer has been used to measure the K-absorption edge structure of Ni^{++}, Cu^{++}, Zn^{++}, $Cu(NH_3)_4^{++}$, and $Cu_2(CN)_4^{--}$ in aqueous solution. It was found that Ni^{++}, Cu^{++} and Zn^{++} have similar edges whose main features may be understood on the assumption that the ions absorb as if they were in vacuum. In each of the three edges two absorption lines have been resolved. Their positions indicate that they are due to excitation of a K electron into the $4p$ and $5p$ orbits of the ion. The solvent does not measurably displace the absorption maxima from the positions calculated for an ion in vacuum but there is considerable broadening of the maxima which must be due to the fields of the coordinated water molecules. The complex ions have quite different absorption edge structures which it is suggested arise from the scattering of the photoelectron by the other atoms of the ion. The same process takes place in the absorption of x-rays in a polyatomic gas.

* Now at the General Motors Research Laboratories, Detroit, Michigan.

103. Radiations from the Induction Accelerator. D. W. Kerst, *General Electric Company.*—Since the x-ray yield from the induction accelerator is now approximately equivalent to that from one gram of radium, it has been possible to take radiographs. The results show that the beam as it impinges on the edge of the target is less than ½ mm in width. Cathode rays coming through the glass walls of the acceleration chamber have also been photographed X-ray absorption curves in copper and lead will be shown for comparison with Van Atta and Northrup's absorption curve for x-rays produced by two million volt electrons.[1] The absorption coefficient for lead is 0.62 cm^{-1} giving a monochromatic equivalent of 1.4 Mev for the x-rays, and for copper the absorption coefficient is 0.454 cm^{-1} which gives a monochromatic equivalent of about 1.35 Mev. The absorption curve indicates that the radiation is thin target radiation. This is to be expected since the electron orbits shrink toward the target and impinge on its outermost edge. Consequently a lower limit can be estimated for the beam current by comparison with thick target yields.[1] This estimate is 0.02 microampere.

[1] Van Atta and Northrup, Am. J. Roent. and Rad. Therapy, Apri 1939.

104. Characteristic X-Rays Produced by Deuteron Bombardment. J. M. Cork, *University of Michigan.*—An investigation has been made of the nature and yield of x-rays produced when thin targets of various elements are bombarded with deuterons of energy up to 10 Mev. The

total radiation from the bombarded target is collimated at right angles to the deuteron beam. The scattered and disintegration particles are deflected out by the strong magnetic field of the cyclotron augmented with a magnetic shunt. At 10 Mev, x-rays shown to be characteristic K radiation, are observed for elements of atomic number less than 39. An apparent maximum occurs for elements of atomic number about 28, due to absorption. The yield of x-rays as a function of the energy of the incident deuteron was observed for a copper target. The results including an estimate of the cross section are compared with the theoretical calculations of W. Henneberg.[1]

[1] W. Henneberg, Zeits. f. Physik **86**, 592 (1933).

105. A New Evaluation of h/e. J. A. Bearden and G. Schwarz, *The Johns Hopkins University.*—Two methods have been used: (1) the high frequency limit of the continuous spectrum with gold and copper targets, (2) x-ray excitation potentials for $K\alpha_1$ lines of nickel, copper, zinc, gallium and the $L\alpha_1$ line of tungsten.

Twenty-eight runs for method (1) and a gold target yield $h/e = 1.3772 \cdot 10^{-17}$ e.s.u. Five similar runs with a copper target give 1.3777. The limit obtained with the copper target is practically as intense as with gold but much sharper. The intensity and sharpness are probably due to the thin layer of tungsten, which deposits by evaporation from the filament. The probable error is about 2 in the last figure and hence we believe the differences between the values for gold and copper is real. The values for h/e obtained with the second method depend greatly upon the target used. For nickel, copper, and tungsten the accuracy of the measurements is better than above and gives $h/e = 1.3793$, 1.3789, and 1.3773, respectively. Differences in the width of the absorption limits may introduce corrections in the last figure. The results for zinc and gallium are less reliable but indicate a value of about 1.3775. These differences within each method and between them, which we believe to be real, indicate that some modification of the simple theory is necessary.

106. The Velocity of Sound in Air. H. C. Hardy and W. H. Pielemeier, *Pennsylvania State College.*—The velocity of sound has been accurately measured by at least fifteen workers since 1900. The values they obtain range from 330.77 to 331.92 meter sec.$^{-1}$ at 0°C. A survey of these values has been made and an attempt will be made to explain this discrepancy. Assuming the experimental technique is correct, the following corrections must be set up in every experiment in order that the values may be compared: (1) The H_2O and CO_2 content must be specified and *properly* corrected for. (2) Correction for temperature and pressure must be accurately made from a dependable equation of state. *In this correction the change of C_v with temperature cannot be neglected.* (3) A dispersion correction must be made for measurements at high frequencies. (4) *The composition* (O_2 and N_2 content) *of the air should be known at the time and place of the measurement.* A calculation of the velocity of sound from known spectrographic data, the Beattie-Bridgman equation of state, and the latest values of the fundamental constants have been made. Assuming a mean density of 1.2930 g/liter^{-1} and a mean composition given by Humphreys,* this value is 331.447 $\pm$0.010 meter sec.$^{-1}$. Due to the variation in the composition of the air, this value should probably be written as 331.45$\pm$0.05 meter sec.$^{-1}$.

* W. J. Humphreys, *Physics of the Air* (McGraw-Hill) third edition p. 67.

107. Supersonic Measurements with a New Apparatus. D. Telfair and W. H. Pielemeier, *Pennsylvania State College.*—The region of acoustical dispersion in a polytomic gas may be explored in three ways besides that of varying the frequency. By varying the density, the temperature, or the foreign gas concentration the acoustical relaxation time may be altered, thus shifting the region of dispersion to a different frequency. An apparatus has been constructed which makes possible a variation of these controlling factors over relatively wide ranges. The gas density and foreign gas concentration may be regulated by using high vacuum technique. The temperature is regulated by means of a thermocouple-controlled photoelectric relay. The sound chamber is made of stainless steel, and by means of a specially designed vacuum-tight joint may be easily opened to insert a quartz plate of the desired frequency. Measurements have been made on velocity in air and velocity and absorption in methane and propylene with interesting results.

108. The Temperature Effect on Ultrasonic Velocities in Carbon Dioxide. C. J. Overbeck and H. C. Kendall, *Northwestern University.*—Ultrasonic velocity measurements in pure carbon dioxide gas were made at temperatures ranging from 25° to 530°C with frequencies from 50 to 147 kilocycles. A sonic interferometer similar to Pierce's employing quartz crystals was used. The interferometer chamber was built of chromium plated brass, glass and quartz to avoid gas contamination at high temperatures. Two sources of carbon dioxide were used: a specially prepared high purity tank of gas, and gas from sublimated dry ice. Traces of water vapor were removed by either dry ice or long phorphorous pentoxide traps. Temperature measurements were made by placing a thermojunction in the middle of the gas space between the crystal and reflector. Frequencies were determined by beating harmonics of the crystal driving oscillator against harmonics of a calibrated standard oscillator. The curves plotted—reduced velocity *vs.* temperature—do not show the irregularities found in published work. Earlier work in this laboratory[1] has shown the effect of gas contamination as a partial explanation of conflicting published results. Recent work has shown that a temperature discrepancy will account for the balance of the variations.

[1] C. J. Overbeck and E. Wiler, Phys. Rev. **55**, 1127 (1939).

109. Sound Velocity and Absorption by Ultrasonic Interferometry. J. C. Hubbard, *The Johns Hopkins University.*—Half-wave-length spacings for determining sound velocity and decrement of corresponding galvanometer or

other readings for determining absorption by the methods of acoustic interferometry are both highly sensitive to boundary conditions. Such data are particularly misleading if there is a periodic error in the screw, if there is a systematic departure from parallelism between source and reflector as distance apart is changed, or if there are measurable diffraction effects. The requirements of design for acoustic interferometry are fully as rigorous as those for optical interferometry and have seldom been met in practice. It is because of this that many have favored optical or other methods of securing acoustic data, but such methods have been used with sound intensities now known to be high enough to account for the great confusion and discord among values found by different observers. The much discussed dispersion of sound in liquids has as yet no basis in experimental measurement.[1] Data are presented showing types of errors encountered and methods of estimating them. Specific application is made to the calibration of screws by ultrasonics.

[1] J. C. Hubbard, Am. J. Phys. **8**, 219 (1940).

110. Friction Phenomena and the Stick-Slip Process. F. MORGAN, M. MUSKAT AND D. W. REED, *Gulf Research & Development Company.*—Further studies* have been made of the stick-slip phenomenon recently investigated by Bowden and collaborators. The apparatus has been modified so as to eliminate radial motion between the slider and rotating table. This change has removed spurious indications of slipping during the stick phase, although under certain conditions some degree of slip appears to be inherent in the process. This aspect of the problem has been studied by quantitative measurements on motion pictures of the slider during stick-slip. Temperature records of the stick-slip cycle confirm previous observations that the temperature flash is confined exclusively to the slip phase and in no case studied exceeds 50°C above ambient. Traces made of the slip phase with very high camera speeds permit an analysis of the variation of the kinetic friction with velocity. Thus both static and kinetic friction data can be obtained from a single stick-slip cycle. Motion pictures of the stick-slip process both for dry and lubricated surfaces will be shown.

* F. Morgan, M. Muskat and D. W. Reed, Phys. Rev. **58**, 205 (1940).

111. Relaxation Time of Colloidal Particles from Measurements of the Electro-optical Effect. B. W. SAKMANN, *Massachusetts Institute of Technology. (Introduced by H. Mueller.)*—The electro-optical effect furnishes a method for the determination of the relaxation time of colloidal particles and, hence, of their size and shape. If the frequency of the electric field is larger than the relaxation frequency, the electric birefringence is steady. For low frequencies the double refraction consists of a steady and a vibrating part; the latter oscillates with twice the frequency of the applied field and lags behind the field. Both parts have been measured in bentonite sols by using a photoelectric method. Measurements of the phase-shift and of the frequency dependence of the alternating part confirm Tummers' theory. The size of the miscelles found by this method shows good agreement with the values determined by the ultracentrifuge.

112. The Velocity of Radio-Waves over Short Distances. R. C. COLWELL, H. ATWOOD, JR., J. E. BAILEY AND C. O. MARSH, *West Virginia University.*—A fixed station at Morgantown sends out sixty pulses per second, each pulse lasting for ten microseconds on a frequency of 3492.5 kc. This signal is received on a portable station so constructed that a thyratron sets off a return pulse with a frequency of 2398 kc. The two pulses appear upon the screen of an oscilloscope at the fixed station with a sweep of 22,800 inches per second. The distance between the two pulses gives the total time taken for the radio-pulse to travel twice the distance between the stations and to pass through the receivers. The portable station then moves to a new place and similar readings are taken. The difference in time for the two positions is the time taken for the radio-pulse to travel twice the distance between the two positions of the portable station. The measured radio-velocity in the line of sight is practically the velocity of light.

113. Transient Current in Dielectrics. KENNETH S. COLE, *Columbia University,* AND ROBERT H. COLE, *Harvard University.*—The complex dielectric constant, ϵ^*, of many liquids and solids is given by[1]

$$\epsilon^* - \epsilon_\infty = (\epsilon_0 - \epsilon_\infty)/[1 + (i\omega\tau)^{1-\alpha}],$$

where ω is the angular frequency, ϵ_0 and ϵ_∞ are the "static" and "infinite frequency" dielectric constants, respectively, τ is a generalized relaxation time and α is a constant, $0<\alpha<1$. The transient current, I, at a time, t, after the application of a unit constant potential difference has been calculated from the above expression in series form. For $t \ll \tau$

$$I = (\epsilon_0 - \epsilon_\infty)(t/\tau)^{-\alpha}/\tau\Gamma(1-\alpha)$$

and for $t \gg \tau$

$$I = (\epsilon_0 - \epsilon_\infty)(1-\alpha)(t/\tau)^{-(2-\alpha)}/\tau\Gamma(\alpha).$$

The center of the transition region between these extremes is near $t=\tau$, and the total charge remains finite as $t \to \infty$. Many data in the literature are of this form although the range of times has not included the entire transition region in any case.

[1] K. S. Cole and R. H. Cole, J. Chem. Phys. **9**, 341 (1941).

114. Small-Ion Content of Air in a Closed Room Occupied by People. G. R. WAIT, *Department of Terrestrial Magnetism, Carnegie Institution of Washington.*—The number of small ions in the air of a closed room diminishes when people occupy the room and rapidly recovers when it is vacated. To understand the cause it is necessary to examine the rate of production and destruction of these ions. The rate of production, as measured with a thin-walled ionization chamber, diminishes when the room is occupied and tends to recover after it is vacated. The cause for this is not fully understood. The rate of destruction is due principally to combination with large ions an

varies with their number and size. The number and size of large ions increase when the room is occupied by people and rapidly recovers when vacated. The increase in number and size of large ions, when the room becomes occupied, appears to be due to an introduction into the room of particles, larger than the ordinary condensation nuclei. These particles are given off by people, principally in their breath.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

National Bureau of Standards

Industrial Building

Session K—Artificial Radioactive Substances

115. Radiations from Radioactive Cobalt. ARTHUR S. JENSEN, *University of Pennsylvania.*—Energy measurements have been made in a cloud chamber in a magnetic field on the particles emitted by radioactive cobalt produced by deuteron bombardment of iron. The sample was separated chemically, and the measurements were made about five months after the activation of the sample so that presumably only the 72-day (Co^{58}) and the 270-day (Co^{56}) isotopes were present. A total of 1410 tracks in helium near atmospheric pressure were measured and the momentum distribution curves plotted. These showed a single positron spectrum with an upper energy limit at 1.36 ± 0.10 Mev. The spectrum of the negative electrons suggests the internal conversion of a γ-ray line near 0.1 Mev; this is confirmed by measurements made with a magnetic spectrograph and reported in another abstract. A few negative electrons of energies up to 0.9 Mev are observed, suggesting the possibility of a feebly converted γ-ray of higher energy.

116. Radioactive Isotopes of Nd, Il and Sm. H. B. LAW, M. L. POOL, J. D. KURBATOV AND L. L. QUILL, *Ohio State University.*—Pr, Nd and Sm have been bombarded with 10-Mev deuterons, 5-Mev protons, neutrons and gammas from deuterons and protons on lithium metal, respectively. Several new periods were found, tentative values of which are listed.

	Pr	Nd	Sm
α	(3.7 hr., 17 hr., 108 days)	(2.3 hr., 10 days)	
d		(2.3 hr., 47 hr., 10 days, 108 days)	(21 mo., 9 hr., 47 hr., 60 days)
n		(2.3 hr., 47 hr., 10 days)	(21 mo., 47 hr.)
p		(2.3 hr., 6 days)	
γ		(2.3 hr., 10 days)	(21 mo., 47 hr.)

In all cases chemical separations were performed to eliminate isotopes that do not follow the rare earths. Since the 108-day period occurs with $Pr+\alpha$ and $Nd+\alpha$ it may be ascribed to $_{61}I^{144}$. The 3.7-hr. and 17-hr. periods found with $Pr+\alpha$ can be analyzed as isotopes which are rare earth group elements after bombardment. The 2.3 hr. may be either $_{61}II^{147}$ or $_{61}II^{149}$ if one postulates a fast period for $_{60}Nd^{147-9}$ which decays by electron emission to Il.

117. Radioactive Isotopes of Iodine. A. ROBERTS AND JOHN W. IRVINE, JR., *Massachusetts Institute of Technology.*—Tellurium bombarded by 11.5-Mev deuterons shows no iodine β or γ activities other than those observed by Livingood and Seaborg.[1] Positron emission is not observed, and constitutes less than 3 percent of the negatron activity 5 days after bombardment. Thus no appreciable I^{124} is formed. We find that a weak iodine activity of half-period about 9 days can be repeatedly extracted from deuteron activated Te targets many months after bombardment. Absorption measurements indicate a spectrum very little different from that of the 8-day I^{131}. The latter grows[1] from isomers of Te^{131} with half-periods 1.2 days and 25 minutes. Other negatron-emitting Te activities are $_{52}Te^{129}$ (32 days), whose daughter has not been previously observed, and $_{52}Te^{127}$ (90 days), which might give a radioactive isomer of the only stable isotope $_{53}I^{127}$. A bombardment of 500 cc ethyl iodide with 70,000 r/cc of 2.0-Mev x-rays gave a chemically concentrated activity of *ca.* 10 counts per minute of half-period >1 day. Assignment of the 9-day activity to I^{129} seems doubtful from total yield considerations. Identification with I^{131} involves the assumption of a third long-lived isomeric state in Te^{131}.

[1] J. J. Livingood and G. T. Seaborg, Phys. Rev. **54**, 775 (1938).

118. Studies with a Permanent-Magnet β-Ray Spectrograph.* ERNST H. PLESSET, *University of Pennsylvania.*—A large permanent magnet β-ray spectrograph has been constructed. For the purpose of checking the absolute calibration of the magnetic field, the β-ray spectrum of RaB has been examined and the measured momentum values compared with those given by Ellis.[1] The agreement is within $\frac{1}{2}$ percent for 10 measured lines. The conversion electrons emitted by a sample of radioactive Co containing the 72-day and 270-day periods indicate γ-ray energies of 119 kev and 132 kev, correct to about 1 percent. A sample of gold bombarded with deuterons shows definite lines corresponding to a 400-kev γ-ray which is doubtless that reported by Lawson and Cork.[2] There is evidence for other lines in this spectrum. The investigation is being continued.

* This research was assisted by a grant-in-aid from the Penrose Fund of the American Philosophical Society.

[1] C. D. Ellis and W. A. Wooster, Proc. Roy. Soc. **A127**, 276 (1927).
[2] J. L. Lawson and J. M. Cork, Phys. Rev. **58**, 580 (1940).

119. Energy of the Hard Gamma-Rays of Radio-Yttrium (100 days). G. SCHARFF-GOLDHABER, *University of Illinois.* (*Introduced by W. E. Good.*)—A source of radio-yttrium[1] of about 30 milligrams radium equivalent in penetrating gamma-rays (generated in the Berkeley cyclotron by deuteron bombardment of strontium) was kindly loaned to us by Dr. Pecher for a study of the neutrons emitted from beryllium under the action of these gamma-rays. In order to determine the neutron energy the photo-neutrons were detected by proton recoils which were produced in a hydrogen filled ionization chamber connected to a linear amplifier. The energy distribution of the recoil protons was found to be very similar to that obtained from the 220-kev neutrons of a Rd Th+D_2O source. From this it was concluded that the photo-neutrons from Rd Y+Be have an energy of 220±20 kev. If the binding energy of the neutron in Be is assumed to be 1.62±0.02 Mev[2], this leads to an energy of 1.87±0.05 Mev for the hard gamma-ray emitted by radio-yttrium. Because of its simplicity this method may prove to be of value for measuring energies of hard gamma-rays.

[1] C. Pecher, Phys. Rev. **58**, 843 (1940).
[2] L. S. Skaggs, Phys. Rev. **56**, 24 (1939).

120. Radioactive Barium from Cesium. H. W. COLLAR, J. M. CORK AND G. P. SMITH, *University of Michigan.*—Radioactivity in cesium and barium has been studied by D. C. Kalbfell and R. A. Cooley.[1] In carrying out a more detailed investigation, two strong activities are observed in the barium separation from cesium bombarded by deuterons. One of these is of particular interest. Cesium has a single isotope of mass 133, so that a (D, n) reaction would give Ba^{134} and a $(D, 2n)$ reaction would result in Ba^{133}. Since Ba^{134} exists in nature, any radioactivity attributed to this isotope can be due only to an excited state of the stable nucleus. This is undoubtedly the case for a barium activity of half-life 39.5 hrs. The radiation is found to consist of gamma-rays and certain groups of beta-particles due to high internal conversion. The peaks corresponding to the ejection of K, L, and M electrons are resolved in the magnetic spectrometer giving for the gamma-ray an energy of 272 kev. The value for the ratio of the K to L, M conversion is about 2.6. The second barium activity has a long half-life and is probably attributable to Ba^{133}.

[1] D. C. Kalbfell and R. A. Cooley, Phys. Rev. **58**, 91 (1940).

121. Beta-Ray Spectra of Scandium. G. P. SMITH, *University of Michigan.*—Calcium metal and calcium oxide have been irradiated with 10-Mev deuterons in the University of Michigan cyclotron. Samples were bombarded for about ten hours, at average beam currents of 9–10 microamperes. The active scandium formed was separated out chemically as the hydroxide. The spectra were measured in a magnetic beta-ray spectrometer of high resolving power, described by Lawson and Tyler.[1] The following spectra have been observed:

β^- 640±7 kev, 44±2 hr. half-life
γ 268±5 kev, 62±5 hr. half-life
β^+ 1.45±0.02 Mev, 4.0±0.1 hr.; 72±6 hr.

The positron spectra have not yet been entirely resolved, but appear to consist of a relatively weak 72-hr., 1.45-Mev activity, and a strong 4-hr. positron, with a slightly lower energy. Further work is in progress.

[1] J. L. Lawson and A. W. Tyler, Rev. Sci. Inst. **11**, 6 (1940).

122. Transmutation of Mercury by Fast Neutrons. R. SHERR AND K. T. BAINBRIDGE, *Harvard University.*—Ten radioactive nuclei have been observed in mercury irradiated with fast neutrons obtained by bombarding lithium with 11.5-Mev deuterons. A trace of gold is amalgamated with several hundred grams of irradiated mercury and recovered by distillation in vacuum. The gold is then dissolved in acid and a Pt-Au chemical separation made. The gold precipitate yields a new period of 48±1 min. and the well-known 65-hr. Au^{198} and 78-hr. Au^{199} periods.[1] The latter can be formed by $n-p$ reactions from Hg^{198} and Hg^{199}. The mercury decay curve shows a feeble activity with period >30 days, in addition to the well-known 43-min. and 25-hr. periods.[1] The platinum precipitate gives: 27±5 min., 85±10 min., 19±2 hr., and >2 days. The first and third are in approximate agreement with the known 31-min. Pt^{199} and the 18-hr. Pt^{197} activities. They can be formed by $n-\alpha$ reactions from Hg^{202} and Hg^{200}. The relative probabilities for $n-\alpha$, $n-p$, and $n-2n$ reactions in mercury are of the order of magnitude of 1, 10, and 10,000.

[1] McMillan, Kamen and Ruben, Phys. Rev. **52**, 375 (1937).

123. Excitation of Nuclei by X-Rays. J. R. FELDMEIER AND GEORGE B. COLLINS, *University of Notre Dame.*—The technique employed by Waldman and Collins[1] in observing the nuclear excitation of lead and indium by x-rays has been used in a search for other nuclei that have low lying metastable levels with activation levels between 0.5 to 1.5 Mev. Counters were constructed with the metal under investigation forming the cylindrical cathode, in order to detect low energy, internally converted electrons that might be emitted by an excited nucleus. The counters were irradiated by placing them directly behind a lead target which was bombarded with electrons from the electrostatic generator. Silver counters showed a 40-second period, which agrees with that observed by Alvarez, Helmholz and Nelson[2] who found isomeric silver formed during the Ag$(d, 2n)$Cd reaction. Cadmium counters gave evidence of a one-hour period which probably corresponds to the 50-minute period observed by Dode and Pontecorvo.[3] Gold, tellurium and tantalum counters were irradiated with x-rays up to 1.5 Mev, but showed no activity. Metastable levels higher than 50 kev with periods between 20 seconds and five hours could have been detected.

[1] B. Waldman and G. B. Collins, Phys. Rev. **57**, 338 (1940).
[2] Alvarez, Helmholz and Nelson, Phys. Rev. **57**, 660 (1940).
[3] Dode and Pontecorvo, Comptes rendus **207**, 287 (1938).

124. Highly Forbidden Transitions in Beta-Decay. R. E. MARSHAK, *University of Rochester.*—There are several beta-emitting nuclei having extremely long half-lives and which therefore undergo large changes of angular momentum. This information may help to decide among

various possible theories of beta-decay which do not involve derivatives of the light particle wave functions. For a given spin change, the vector interaction (Fermi) gives a lifetime $(c/v)^2$ (v is the velocity of the nuclear particle) longer than the pseudovector interaction (Gamow-Teller) whereas the scalar theory gives a lifetime $(\lambda\!\!\!^{-}/R)^2$ (R is the nuclear radius, $\lambda\!\!\!^{-}$ an average wave-length of the electron) longer than the pseudo-vector theory. A calculation has been performed for K^{40} which has a maximum electron energy of 0.7 Mev and a half-life of $1.4 \cdot 10^9$ years.[1] The only possible spin changes are 3 or 4. The first choice is indecisive but if the second is true, the Gamow-Teller theory would just agree with the observed lifetime—somewhat longer—the Fermi theory would give a fifty times longer lifetime, while the scalar theory would give a hundred times still longer lifetime. The experimental material would then be too uncertain to decide between the Gamow-Teller and Fermi theories but it would seem to definitely exclude the scalar interaction.

[1] A. Bramley and A. K. Brewer, Phys. Rev. **53**, 502 (1938).

SATURDAY MORNING AT 9:30 O'CLOCK

National Academy of Sciences

Auditorium

Session L—Magnetism and Metals

125. Ferromagnetic Impurities in Copper, Brass and Silver. F. W. CONSTANT AND R. E. FAIRES, *Duke University.*—As previously reported, small amounts of ferromagnetic impurities have been found in copper wire, commercial brass and C. P. silver which could not be attributed to surface effects. Further study has been made to determine whether such impurities might be rendered nonmagnetic through heat treatment. In the case of copper and brass, heating for several hours at 900°C and 800°C, respectively, in a hydrogen atmosphere and then quenching completely removed all trace of magnetism (although most of the disappearance occurred around 700° and 500°). But in the case of silver heat treatment had comparatively little effect. This seems understandable if the magnetic impurity is chiefly iron, which at high temperatures can change from a body-centered to a face-centered lattice and so dissolve in the copper lattice in a metastable state, while for silver this is impossible since the metals do not form solid solutions. Heat treatments at intermediate temperatures in various atmospheres have shown that the ferromagnetism may be strongly accentuated. Hysteresis loops were taken before and after treatment.

126. Measurement of the Magnetic Susceptibility of Vapors. R. K. REBER AND G. F. BOEKER, *The City College of New York.**—An apparatus has been developed to measure the magnetic susceptibilities of vapors of substances which are liquids or even solids at room temperatures. The design of the apparatus makes it possible to make measurements at temperatures up to 300°C and at independently controlled pressures of one atmosphere and less. The measurements consist of compensating the twist produced by a test body in a nonhomogeneous magnetic field by the rotation of the suspension support. The temperature is controlled by the circulation of liquid from a thermostatically controlled bath through a jacket which completely surrounds the test unit. The pressure control consists of a tube which dips into a reservoir of the liquid and which is non-uniformly heated so as to get progressively hotter towards the top. The upper end of the tube leads to the apparatus. An external gas pressure on the liquid in the reservoir forces it up the tube until an equal vapor pressure is established. This arrangement permits the pressure to be read externally on a manometer. Measurements on several diamagnetic vapors at 110°C have shown that results can be duplicated to within one percent.

* Research done in laboratories of Columbia University.

127. Paramagnetic Disperion. C. STARR, *Massachusetts Institute of Technology.*—The dispersion at radiofrequencies of the paramagnetic susceptibility of several salts of the iron group has been measured at liquid nitrogen and room temperatures. An improved beat frequency method was used to determine the high frequency susceptibility. At any frequency, the dependence of this susceptibility upon the value of the applied constant magnetic field was determined from the change in the audiofrequency beat note. The measurements were made at various frequencies up to 10 megacycles and at constant magnetic field strengths up to 50,000 gauss. The results at 77°K and 10 megacycles for ferric alum, when compared with the results of du Pre[1] at liquid helium temperatures and 60 cycles, indicate that the thermodynamic theory of Casimir and du Pre[2] is valid over this temperature range. This agrees with the recent results of Teunissen and Gorter[3] at 7 megacycles which indicated that previous experimental deviations from the thermodynamic theory resulted from erroneous absorption measurements and the use of frequencies not sufficiently high. The effect predicted by Kronig and Bouwkamp[4] for large values of the applied field was not found.

[1] du Pre, Physica **7**, 79 (1940).
[2] Casimir and du Pre, Physica **5**, 507 (1938).
[3] Teunissen and Gorter, Physica **6**, 1113 (1939).
[4] Kronig and Bouwkamp, Physica **6**, 290 (1939).

128. On the Mechanism of Paramagnetic Relaxation at Helium Temperatures. J. H. VAN VLECK, *Harvard University.*—I have shown elsewhere[1] that the conductivity of lattice oscillators at helium temperatures is insufficient to make them serve as a thermostat in the way ordinarily assumed in the theory of paramagnetic relaxation. Consequently, it is not surprising that calculations based on the usual assumptions fail completely in the helium domain. The following substitute mechanism is now suggested. When a paramagnetic ion reverses its spin, it emits a virtual vibrational quantum, which is absorbed in the surrounding liquid helium in virtue of the latter's anharmonic terms. Thus, the conductivity takes place via virtual rather than real lattice waves, and the coupling between the spins and the helium bath is reminiscent of the interaction formalism in nuclear field theories except that the ghost lattice waves replace the transient particle (e.g., mesotron) as the intermediary. With this model, Casimir and du Pre's thermodynamic formulas preserve their validity. In addition, the new theory appears to give correct relative magnitudes of the relaxation time τ for the different alums, and also the proper dependence of τ on the applied magnetic field and on the temperature.

[1] J. H. Van Vleck, Phys. Rev. to be published.

129. Magnetic Properties of Antimony-Tin Crystals at Low Temperatures. S. H. BROWNE AND C. T. LANE, *Yale University.*—Temperature dependence of the magnetic susceptibility in monocrystals of pure antimony and antimony alloyed with small percentages of tin has been investigated in the range from 295°K to 77°K. The measurements were made with a Sucksmith balance modified to allow the use of crystals in the form of long cylindrical rods. Results are given for the temperature dependence of both the susceptibility parallel to the principal axis of the crystal ($\chi_{\parallel}$) and also perpendicular thereto ($\chi_{\perp}$). For antimony and antimony-tin solid solutions (0.48, 1.05, 2.24, 4.10 atomic percent Sn), $\chi_{\perp}$ is sensibly independent of temperature and diamagnetic. However $\chi_{\parallel}$ is temperature dependent. For pure antimony and up to about 1 percent Sn the diamagnetism was found to increase with decreasing temperature. Above 1 percent Sn $\chi_{\parallel}$ becomes paramagnetic and this paramagnetism increases as the temperature falls. A plot of $\chi_{\parallel}$ *versus* $1/T$ gives a curve which, in all cases, is in close agreement with that predicted by the Bloch theory. In consequence it is possible to estimate the degeneracy temperature of electrons in antimony as approximately 600°K. Essentially the same value was found for all percentages of tin. Further it is shown that the amount of overlap into the second zone in antimony (approximately 10^{-2} electrons per atom) is closely temperature independent in the range of temperature studied.

130. Magnetic Domain Size Determined from Measurements of Damping in 68 Permalloy. H. J. WILLIAMS AND R. M. BOZORTH, *Bell Telephone Laboratories.*—When a ferromagnetic material is subjected to small periodic stresses there are energy losses due to eddy currents and magnetomechanical hysteresis, and these are generally large compared to the losses in nonferromagnetic materials subjected to similar stresses. In theory the losses in ferromagnetic materials have been put into three classifications by Becker and Döring:[1] macro-eddy-current, micro-eddy-current, and magnetomechanical hysteresis. When the material is unmagnetized, the macro-eddies will be zero; that part of the logarithmic decrement that is due to micro-eddies is proportional to frequency and depends on domain size; that due to magnetomechanical hysteresis is independent of frequency. The decrement has been determined for an 80-cm bar of unmagnetized 68 Permalloy and plotted as a function of frequency. A straight line is obtained and from its slope the size of the domains (assumed cubic in form) is found to be 10^{-3} cm[3], a value agreeing closely with that obtained previously from Barkhausen experiments.[2]

[1] R. Becker and W. Döring, *Ferromagnetismus* (Springer, Berlin, 1939).
[2] R. M. Bozorth and J. Dillinger, Phys. Rev. **35**, 733 (1930).

131. Transitions in Alloys of Cobalt Nickel and Iron by the Hydrogen Diffusion Method. W. R. HAM AND F. D. BENNETT, *The Pennsylvania State College.*—The measurement of the rate of hydrogen diffusion through metals provides a sensitive and accurate method of detecting transition points in the metal lattice. For a homogeneous metal or alloy the diffusion rate is given by

$$R = \text{const.}\ p^{z} \cdot \epsilon^{-b/T},$$

where z is usually $\frac{1}{2}$. An examination of two Ni-Co alloys shows that while the physical magnetic change occurs at 600° and 910°, respectively, the Curie point break for Ni is still present in the diffusion curve. This fact indicates a fundamental electronic transition in Ni at 360° not necessarily associated with any magnetic change in the alloy. An Fe-Ni alloy in which the magnetic transition is depressed to 340° shows a marked discontinuity at 768°, the temperature at which the magnetic change in pure Fe takes place. The magnetic transitions of pure Ni and Fe appear to take place in two distinct steps. From the straightness of the diffusion curve one may also infer that no electronic rearrangement is associated with the phase changes in pure Fe or Co, at 910°C and 440°C, respectively.

132. The Thermal Expansion of Pure Metals: Iron, Nickel, Copper, Gold and Aluminum. F. C. NIX AND D. MACNAIR, *Bell Telephone Laboratories.*—Extremely accurate determinations of the linear thermal expansions have been made interferometrically[1] from −196°C to temperatures about +400°C for Al and +700°C for Fe, Ni, Cu and Au. The relationship between true thermal coefficient of expansion and temperature conforms very well to the Grueneisen-Debye theory when values are chosen for the Debye characteristic temperatures which turn out to agree well with those chosen to achieve agreement with the Debye theory of specific heats. Our values for these characteristic temperatures are: 410°K for Ni, 420°K for Fe, 400°K for Al, 325°K for Cu and 190°K for Au. The magnetic Curie temperature for Ni is found to be 352°C. In plotting true coefficient of thermal expansion *versus* temperature Simon and Bergmann[2] found a hori-

zontal plateau at *ca.* −50°C to −100°C for Ni and Fe; but we do not confirm this.

[1] F. C. Nix and D. MacNair, Rev. Sci. Inst. **12**, 66 (1941).
[2] F. Simon and R. Bergmann, Zeits. f. Physik **8B**, 255 (1930).

133. Elasticity in Order-Disorder Transformations. H. F. LUDLOFF, *Cornell University.*—It was suggested by the author that the temperature curve of an isothermal and corresponding adiabatic elastic modulus through the temperature region of order-disorder transformations might be measured by determining there two proper-frequencies of an appropriate vibrating sample of the alloy considered. To find appropriate conditions for such a method, the temperature distribution in such a sample has been computed for different vibration types and sample forms, since the value of the amplitude of the temperature fluctuation indicates the isothermal or adiabatic character of the vibration. One finds that for plates, reeds, roads, loops there is a set of antisymmetrical (bending) vibrations which for appropriate sample dimensions contains an isothermal ground tone and an adiabatic overtone. In the low frequency range the variation of Young's modulus E is:

$$E(\omega)-E_{is}\sim(E_{ad}-E_{is})\omega\left\{\frac{1}{(\omega^2+(\pi^4/a^4)\cdot D^2)^{\frac{1}{2}}}+\cdots\right\},$$

ω frequency, a thickness, D thermal conductivity. The $E(\omega, T)$-curves through the transition region can be illustrated by means of available experimental data.

134. Some Measurements of the Temperature Dependence of Young's Modulus of β-brass and Certain Other Metals. P. G. BOHLKE, T. R. CUYKENDALL AND H. S. SACK, *Cornell University.*—For the study of certain elastic properties of solids, an apparatus has been constructed which employs a vibrating reed of the solid in question. The reed vibrates transversely at a medium frequency, 90 to 6000 c.p.s. These vibrations, excited by electrostatic forces, modulate a beam of light and thereby allow their study with a photo-cell and a linear amplifier. The sensitivity of the arrangement is such that amplitudes of vibration of the order of 0.01 mm may be measured. The reed, placed in a temperature controlled furnace, exhibits vibration resonance phenomena and the resonance frequencies occuring up to 700°C have been measured. From these data, the temperature dependence of Young's modulus of polycrystalline β-brass in the phase transition region has been calculated.

135. The Evaporation of Molten Metals from Hot Filaments. WALLACE C. CALDWELL, *Iowa State College.* (*Introduced by Percy H. Carr.*)—Several investigators have used the evaporation technique for making surface mirrors, thermocouples, high resistances, and other devices. The method usually used involves attaching the metal to be evaporated to a refractory filament that is heated electrically. Tungsten was nearly always used as the filament until recently other filament materials have been found preferable. In the present investigation a determination of the best filament to be used with each metal was made. In order that a metal evaporate from a filament satisfactorily the metal must adhere to the filament, must have sufficient vapor pressure to evaporate while still at a temperature below the melting point of the filament material, and must not form with the filament an alloy which has a melting point below the temperature at which evaporation will ensue. Acquiring a knowledge of the degree to which the filament material meets these requirements has made possible the selection of the filaments most suitable for the evaporation of each of the metals investigated.

136. On the Theory of Secondary Emission. H. A. BETHE, *at present at Columbia University.*—The secondary electron emission (SE) from solids is proportional to the ratio of the rates of energy loss (REL) of primary particle and secondary electron, the number of secondaries per primary being about $\frac{1}{10}$ to $\frac{1}{4}$ of that ratio. This is demonstrated by the large SE produced by protons and especially He^+.[1] From the known REL of protons (≈30 ev/A in Cu at 200 kv) and the measured SE (3 electrons/proton) the REL of the secondaries is calculated ≈1.5 ev/A. From measurements with primary electrons, we find the REL to increase with energy up to about 500 ev where REL ≈10 ev/A. In insulators, the REL of the secondaries is extremely small because they cannot give energy to electrons in the filled bands; hence the large SE of insulators.[2] In alkalies, the conduction electrons are nearly free and are therefore ejected mostly at right angles to the primary; therefore the SE increases strongly with the angle of incidence θ of the primary and is very low for $\theta=0$. Experiments with primary protons would give most information.

[1] A. G. Hill, W. W. Buechner, J. S. Clark and J. B. Fisk, Phys. Rev. **55**, 463 (1939).
[2] H. Bruining and J. H. de Boer, Physica **5**, 17, 901, 913 (1938); **6**, 823, 834, 941 (1939).

SATURDAY MORNING AT 9:30 O'CLOCK

National Academy of Sciences

Lecture Hall

Session M—Mainly Reactions of Transmutations

137. Radiations from $I^{131}\rightarrow Xe^{131}$. MARTIN DEUTSCH, *Massachusetts Institute of Technology.*—Radiations emitted in the disintegration $I^{131}\rightarrow Xe^{131}$ (8 day) have been studied by means of a magnetic lens beta-ray spectrometer.[1] I^{131} was grown from Te^{131} formed by a Te (d, p) reaction. The maximum energy of the beta-rays was found to be

0.595 ± 0.015 Mev as compared with 0.687 Mev found by Tape[2] in a cloud chamber. One gamma-ray was found to have an energy of 0.364 ± 0.02 Mev from the energy of internal conversion electrons. It is estimated that the conversion coefficient for this gamma-ray is about 1 percent with conversion in the K shell at least five times as probable as in the L shell. By studying coincidences between beta-rays focused in the spectrometer and gamma-rays it was found that no transitions take place to the ground state of Xe^{131}. Coincidences between conversion electrons and beta-rays indicate that the most energetic beta-rays are probably emitted in transitions to a level 0.364 Mev above the ground state of Xe^{131}. The presence of a soft component of maximum energy less than 0.3 Mev is also indicated by the coincidence spectrum.

[1] M. Deutsch, Bull. Am. Phys. Soc. **16**, No. 1, 7 (1941).
[2] G. F. Tape, Phys. Rev. **56**, 965 (1939).

138. Coincidence Study of the Decay of Br^{82}. J. R. Downing and A. Roberts, *Massachusetts Institute of Technology.*—$\beta\gamma$ and $\gamma\gamma$ coincidences are observed in the radiations from Br^{82}. The number of $\beta\gamma$ coincidences per 1000 β-rays is independent of absorber thickness. Thus the β spectrum is simple. The γ-ray absorption curve indicates an energy of about 1.0 Mev. and remains a simple exponential over an intensity range of at least 30. We estimate not more than 10 percent higher energy radiation present. No x-rays were found; thus internal conversion or K capture takes place in less than 5 percent of the disintegrations. The ratio of $\beta\gamma$ coincidences per 1000 β's to $\gamma\gamma$ coincidences per 1000 γ's is 1.53 ± 0.06, indicating 3 quanta per disintegration. The γ-counter efficiency for quanta in this energy range was determined with Mn^{56} assuming the levels reported by Langer, Mitchell and McDaniel.[1] The high energy portion of this spectrum yielded 1.07 ± 0.03 $\beta\gamma$ coincidences per 1000 β's as compared with 3.44 ± 0.06 in Br^{82}. The Br γ-ray, being slightly more energetic, has a somewhat higher efficiency for detection than 0.107 percent, giving excellent agreement with the assignment of 3 quanta per Br^{82} disintegration. An estimate of the spins of the Kr^{82} levels has been made.

[1] Langer, Mitchell and McDaniel, Phys. Rev. **56**, 422 (1939).

139. Proton-Induced Fission. G. Dessauer and E. M. Hafner, *University of Rochester.*—The 6.9-Mev beam of the Rochester cyclotron was employed in looking for proton-induced fission. Our method of detection is similar to that of Gant.[1] With a thorium target and a bombardment of 25 μ Ah within 8 hours, radioactivity was observed on an aluminum catching foil whose decay could be followed for over 60 hours. The decay curve showed the curvature characteristic of a mixture. After a check bombardment with identical geometry with respect to the catcher, but with the proton beam striking the other side of the thorium sheet, no activity was observed. This rules out fission due to the neutron background, and to neutrons produced by protons in the target itself. The threshold for proton-induced fission of the compound nucleus in question, namely, Pa^{223}, is below 5.8 Mev, as indicated by excitation data. The range of the fission fragments lies below 0.7 mil of aluminum.

[1] D. H. T. Gant, Nature **144**, 707 (1939).

140. Fission Tracks on the Photographic Plate. K. Lark-Horovitz and W. A. Miller,* *Purdue University.*—Photographic plates (Eastman fine-grain α, Ilford R_2), bathed in alcoholic solutions of uranium nitrate and thorium nitrate have been exposed to slow and fast neutrons and the resulting tracks have been measured microscopically with a filar micrometer. With fast neutrons new types of tracks besides the ordinary alpha-particle tracks have been observed on both the U and Th treated plates; with slow neutrons these tracks have been found only on the U plate. We conclude that these tracks are due to fission fragments because: (a) Their range is different from the range of the U α-particles. (b) The reciprocal grain spacing decreases toward both ends of the track, in contrast to the appearance of α-tracks. (c) Distribution curves of the observed grain spacings show a minimum distance far more frequently than with α-tracks. (d) Recoil protons issuing from the track are frequently found; and from stereoscopic projection their energy can be estimated and related to the energy of the fission product at this point of the path in good agreement with the calculation of Knipp and Teller.[1] Most of the tracks are assymetric but some symmetric tracks have been observed. To study fission processes due to cosmic radiation, U and Th treated plates as well as plates treated with thallium iodide solution have been sent into the stratosphere reaching a height of about 30 km. Fission tracks like the ones observed in the laboratory were obtained only on the U plate but not on the Th plate indicating that most of the neutrons in the cosmic radiation even at this altitude are too slow to produce the fission.

* Purdue Research Foundation Fellow.
[1] J. Knipp and E. Teller, Phys. Rev. to be published.

141. Deuteron-Tritium Reaction in Nitrogen. Lyle B. Borst, *University of Chicago.* (*Introduced by H. W. Newson.*)—The reaction Be^9 (d, H^3) Be^8 has been established[1] and there are indications of similar reactions[2] in Cu^{63} and Ag^{107}. It therefore seemed desirable to look for other examples of this reaction. The reaction N^{14} (d, H^3) N^{13} has been established and its excitation function measured. The threshold was found to be 6.8 ± 0.1 Mv. Calculations from the masses give $Q = -4.54$ Mv, so that the H^3 nucleus emerges with an energy of 2.2 Mv. The value of the potential barrier involved is 2.6 Mv. Aluminum was similarly studied, but no indication of the reaction was found with 8.2 Mv deuterons. In this case $Q = -5$ Mv, and the potential barrier, 3.4 Mv, so that by analogy the threshold should be about 8 Mv, and consequently difficult to observe at the energy used.

[1] R. D. O'Neal and M. Goldhaber, Phys. Rev. **57**, 1086A (1940).
[2] Krishman and Gant, Nature **144**, 547 (1939); Krishman and Banks, Nature **145**, 777 (1940).

142. The Determination of Nuclear Reaction Energies for a Mixture of Copper Isotopes. Henry W. Newson and Lyle B. Borst, *University of Chicago.*—The ranges of

four groups of protons from Cu (d, p) have been measured by Davidson[1] who found Q's of 6.35, 5.70, 4.35 and 3.54 Mv. We have measured the angular distribution of the radioactive recoil atoms in an attempt to assign each of the above groups to the proper isotope of copper. The results are definite to the extent that the cut-off angle for Cu^{66} is decidedly higher than that for Cu^{64}; the first group must therefore be assigned to Cu^{66}. The distribution of Cu^{64} shows little curvature at large angles, and indicates a single group with $Q=5.6$ Mv. This value agrees with the second of the above groups; the same assignment was made by Davidson because of the relative intensities. The shape of the Cu^{66} distribution shows a decided curvature which indicates the presence of at least two groups: the first and third. The fourth group is uncertain, but it seems most likely that it belongs to Cu^{66}.

[1] W. L. Davidson, Phys. Rev. **56**, 1062 (1939).

143. Distribution with Angle of Protons from D-D Reaction. H. P. Manning, C. M. Grenshaw and V. J. Young, *New York University.*—A thin D_2O vapor target was bombarded with deuterons. Following previous investigators,[1] the distribution of protons in the center of mass coordinate system was found to be well represented by $1+A\cos^2\theta$ where A is a function of bombarding energy. The following values of A and their probable errors were obtained:

kv	A	kv	A
100	0.49±0.09	180	0.80±0.08
110	.50± .04	183	.86± .04
125	.51± .12	190	.76± .07
140	.58± .05	200	.87± .03
150	.72± .02	220	.90± .06
160	.66± .05	240	1.00± .11
167	.75± .06	250	0.98± .09
175	.70± .03		

These A values may be represented by $A=a+bE$ where $a=0.11\pm0.05$ and $b=0.37\pm0.03$. Energy measurements are good to better than 5 percent.

[1] R. D. Huntoon, A. Ellett, D. S. Bayley and J. A. Van Allen; Phys. Rev. **58**, 97 (1940).

144. Disintegration of Nitrogen and Oxygen by Neutrons. W. Hansen, *Yale University.* (*Introduced by A. F. Kovarik.*)—An amplifier employing inverse feedback and which satisfies the conditions of Johnson and Johnson[1] has been constructed and used with a parallel-plate ionization chamber to study the reactions

$$N^{14}+n^1\rightarrow B^{11}+He^4,$$
$$N^{14}+n^1\rightarrow C^{14}+H^1,$$
$$O^{16}+n^1\rightarrow C^{13}+He^4.$$

Neutrons from the bombardment of Be and Li by deuterons in a cyclotron were used. The pulses on a cathode-ray oscilloscope screen were photographed and the distributions of number of pulses *versus* energy were plotted. The distributions for nitrogen showed numerous peaks separated by about 0.2 Mev, in agreement with the work of Thibaud and Comparat.[2] A larger average spacing at higher energies is indicated. The interpretation of these results is uncertain, but it is likely that they are correlated with the energy levels of the compound nucleus.

[1] Johnson and Johnson, Phys. Rev. **50**, 170 (1936).
[2] Thibaud and Comparat, J. de phys. et rad. **10**, 161 (1939).

145. Alpha-Proton Reactions of Sodium and Aluminum. Richard F. Humphreys and Ernest Pollard, *Yale University.*—To investigate the possibility of the operation of selection rules in transitions from the compound nucleus to energy levels near the ground state it is necessary to observe the energy levels found in different reactions which give the same final nucleus. We have previously reported levels in Mg^{26} and Si^{30} formed by deuteron bombardment of magnesium and silicon, and compared the results with the known results of alpha-particle bombardment of sodium and aluminum, in which natural sources were used. We have now repeated these experiments with alpha-particles of 7.4 Mev from a cyclotron with much better angular conditions and find that the older work is not complete. In the case of aluminum we find, in addition to the well-known groups corresponding to two states of excitation, some nine groups. These are found when a thin layer is bombarded by reasonably homogeneous particles whose energy, moreover, is in excess of the barrier height and so the groups are not due to resonance. If it is assumed that all the previously assumed resonance levels are in reality true levels in the Si^{30} nucleus then the present measurements are in good agreement with older work. Excited states of the Mg^{26} nucleus were found at 0.23, 0.60, 1.18, 1.92, and 2.75 Mev. The complete level scheme for Si^{30} is not yet determined, but the spacing of the groups is definitely less than 1 Mev in place of greater than 2 Mev as formerly thought. It seems likely that the level spacing in the moderately light nuclei is much smaller than the generally published figures.

146. Energy Levels of S^{33} by Deuteron Bombardment of S^{32}. E. Smith and Ernest Pollard, *Yale University.*—Measurements of the yields of protons from the deuteron bombardment of sulphur indicate that there are six definitely resolved groups due to transitions to the ground and five excited states. The energy change values we find are as follows: 6.62, 5.57, 4.45, 3.40, 2.29 and 1.30 Mev. The yields of the groups are roughly in the ratios 1 : 1 : 1 : 3; 3 : 6. The average spacing is therefore about 0.9 Mev which is of the same size as found for other neighboring nuclei.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

National Academy of Sciences

Lecture Hall

Session N—Solid State

147. The Electrical Properties of Zinc Oxide. PARK H. MILLER, JR., *University of Pennsylvania.*—The electrical conductivity of zinc oxide is found to obey the usual law for semi-conductors $\sigma = Ae^{-E/kT}$ for temperatures below 100°C, where the activation energy E varies between 0.01 and 0.1 volt depending on the past history of the sample. When kT vecomes the same order of magnitude as E this equation is no longer valid because most of the electrons have left the bound levels. However, this same type of equation does hold in the temperature range of 450°C to 700°C with E having a value between 0.5 and 1.0 volts. The conductivity changes because the effective number of interstitial zinc atoms increases and not because a second electron is being evaporated into the conduction band. The conductivity is oxygen pressure dependent obeying the law $\sigma = cp^{-\frac{1}{4}}$. This activation energy of 0.5 to 1.0 volt is not the energy required to evaporate oxygen atoms from the lattice because we would expect this energy to be about 5 volts and the time required to reach oxygen equilibrium with well centered samples is of the order of days and these measurements required only several hours. This indicates there is probably a "coagulation" of the interstitial zinc atoms with their electrons and the activation energy associated with this process is about one volt. The activation energy for the diffusion of zinc atoms in the lattice is 2.2 volts as measured by a sectioning method employing radioactive Zn^{65} as a tracer. The ionic conductivity calculated from the measured diffusion constant is 10^{-4} times the observed conductivity at 900°C.

148. The Electrical Conductivity of Titanium Dioxide. MARSHALL D. EARLE, *University of Pennsylvania.*—Detailed studies were made of the electrical conductivity of titanium dioxide as a function of the oxygen pressure surrounding the sample and also as a function of the temperature between 500 and 1000°C. Both the rutile and anatase modifications of titanium dioxide were studied, most of the work being done on rutile. In the range of temperature investigated it was found that the variation of conductivity with temperature is well represented by the equation $\sigma = Ae^{-\epsilon/kT}$ for both porous and well sintered samples, the value of ϵ, the activation energy, in both cases being approximately 1.7 ev. The variation of conductivity with oxygen pressure obeys very closely the formula $\sigma = Pe^{-1/n}$ (where n is a constant), for the pressure range of 30 to 800 mm of mercury. The agreement below 30 mm was poorer, the slope being too steep, indicating a greater conductivity than that predicted, which is probably due to small impurities in the samples used. Transport measurements were made on well-sintered samples of rutile. The results showed the ionic conductivity to be negligible. In the measurement of the Hall effect it was found that the Hall constant was very small being of the order of -10^{-7} volt-cm/amp.-gauss. Indicating that the mean free path of the conduction electrons is probably very small. These experiments indicate that titanium dioxide is a reduction semi-conductor of the same type as zinc oxide.

149. Dislocations in NaCl. H. B. HUNTINGTON, *University of Pennsylvania.*—Much of the observed behavior of plastic flow has been explained by the theory of linear dislocations as developed by Taylor and others. The stress energy of such a dislocation can, at large distances, be treated by the standard methods of elasticity. Inside a cylinder, with radius of atomic dimensions about the dislocation line, the strains can no longer be treated as small. A detailed calculation of the energy in this region has been carried through for an alkali-halide, NaCl, making use of short range repulsive and electrostatic forces between rows of ions. The dislocation has been orientated so that slip occurs in the (110) direction along the (110) slip plane to agree with observation. Qualitative reasons will be presented to show why this orientation would be expected. The stress energy in the immediate neighborhood of the dislocation is less than 1 ev per atomic plane, as compared with about 2.5 ev per atomic plane found for the region of elastic strain.

150. The Energy Stored During Work Hardening. J. S. KOEHLER,* *University of Pennsylvania.*—A calculation of the energy which is stored in a solid when it undergoes work hardening has been made using the theory of dislocations. Following Taylor[1] a work-hardened material is assumed to contain many dislocations arranged in a regular two-dimensional lattice. The energy required to produce a dislocation in such a lattice is the energy required to form an isolated dislocation minus the binding energy of a dislocation in the lattice. The energy required to produce an isolated dislocation is found to be about 2.8 ev per atomic plane in copper. Taking the density of dislocations to be 10^{12} per cc.[2] the binding energy of a dislocation in a lattice is found to be 1.3 ev per atomic plane in copper. The energy stored in the process of work hardening in copper thus becomes 0.30 cal. per gram. The experimental value is 0.5 cal. per gram.[3]

* Rackham Postdoctoral Fellow of the University of Michigan.

[1] G. I. Taylor, Proc. Roy. Soc. **A145**, 362 (1934).

[2] W. F. Brown, Jr. Phys. Rev. **59**, 528 (1941); F. Seitz and T. Read, J. App. Phys. **12**, 178 (1941).

[3] G. I. Taylor and H. Quinney, Proc. Roy. Soc. **A143**, 307 (1934); *ibid.* **A163**, 157 (1937).

151. The Generation of Dislocations in Polycrystalline Copper. A. W. LAWSON, *University of Pennsylvania.*—The internal friction of oxygen-free polycrystalline copper has been studied as a function of applied compressive stress. It is found that the internal friction increases to a maximum and then decreases somewhat as the stress increases. The maximum increase in internal friction is approximately 100 percent. Corresponding to the maximum in internal friction, a minimum in Young's modulus occurs. The maximum decrease in the latter quantity is about 6 percent. This effect seems to be nearly temperature independent from the temperature of liquid nitrogen up to the recrystallisation temperature of copper. Although the Taylor dislocation model of plasticity seems capable of explaining qualitatively the form of the curves at any given temperature, it seems incapable of explaining, at least at the present stage of its development, the temperature independence of the observed effect.

152. Electron Emission from Surfaces Subject to Periodic Fluctuations in Work Function. A. T. WATERMAN, *Yale University.*—The usual calculation of the electron current density from a metallic surface assumes a potential barrier or work function which is uniform over the surface and invariable with time. This approximation implies that the use of a mean work function is legitimate and is justified by the degree of agreement between theory and experiment. With increasing study of local differences in work function from a given surface it is a matter of interest to know what sort of mean the observed work function represents and what its expected properties may be. To examine this matter briefly and simply, the thermionic current density is calculated from a plane emitter of the usual idealized variety except that small perturbations, which take the form of standing waves, occur in its work function. If χ is the amplitude of such a wave, then the perturbation contributes an effective work function which is less than the unperturbed one by an amount χ^2/kT. The possible consequences of this result are discussed in their application to thermionic and photoelectric emission and the temperature dependence of the work function.

153. The Measurement of Self-Diffusion in Zinc Single Crystals. FLOYD R. BANKS, *Morgan State College,* AND PARK H. MILLER, JR., *University of Pennsylvania.*—Radioactive Zn^{65} was electroplated on the plane and parallel ends of single crystals of pure zinc (1 cm diameter, 2 cm long). The crystals were annealed at several different temperatures for predetermined periods, sectioned in a lathe, and the diffusion coefficient D determined as in the previous work of Banks.[1] The orientation of the c axis with respect to the plane end of the crystals was determined after heat treatment from a back-reflection Laue photograph .The diffusion coefficient perpendicular to the c-axis, D_2, was calculated for each crystal, using the value of the diffusion coefficient parallel to the c axis (D_1) previously determined, and the value for D obtained in this experiment. The preliminary value of the activation energy Q_2 perpendicular to the c axis, obtained from the temperature dependence of D ($D \pm Ae^{-Q/RT}$) is 28,600 cal. per mole, a value approximately fifty percent larger than that of Q_1 (19,600 cal. per mole) previously reported[1] for the activation energy parallel to the c axis. Surprisingly, however, A_2 is about 10^3 times larger than A_1.

[1] F. R. Banks, Phys. Rev. **59**, 376 (1941).

154. Field Dependence of the Surface Photo-Effect. CHARLES J. MULLIN AND EUGENE GUTH, *University of Notre Dame.*—The photoelectric current emitted under the influence of an applied electric field is found to contain a term analogous to the Schottky term for thermionic emission and also a term periodic in the field intensity similar to that recently found and explained for thermionic emission.[1] If frequencies near the threshold are used, then for fields of 3×10^5 volts cm^{-1} the periodic term has a magnitude of about four percent of the nonperiodic part of the current. If the photoelectric threshold frequency for zero field is used to eject the electrons, the resultant plot of the nonperiodic part of the photo-current against the field is a straight line for high field intensities. This line gives the most convenient reference system for observing the periodic term; in addition, the use of the zero field threshold gives the fractional magnitude of the periodic term a relatively large value.

[1] E. Guth and C. J. Mullin, Phys. Rev. **59**, 575 (1941).

155. Average Thermionic Constants for Single Crystal Tungsten Wire. MYRON H. NICHOLS, *Princeton University.*—Experimental data have clearly demonstrated that different crystal surfaces of the same metal have different work functions. Consider a thermionic emitter whose surface is made up of different crystal surfaces or patches having different work functions. Group these patches according to their work functions. For sufficiently large collecting field strengths, the total emission is

$$i = \sum_n i_n = \sum_n A_n^* T^2 \exp(-e\varphi_{0n}/kT),$$

where i_n is the emission from the nth group of patches whose thermionic constants are φ_{0n} and A_n^*. Using values of φ_{0n} taken from experiments on single crystal tungsten wires[1] and 120 amp./cm^2 T^2 for A_n^*, it can be shown that the average thermionic constants φ_0' and $A^{*\prime}$ for such wire should be close to 4.40 volts and 40 amp./cm^2 T^2. This is not in agreement with the accepted values of 4.50 and 60 for pure tungsten wire retaining the drawing die marks. To test this result, the average thermionic constants of a G. E. type 218 tungsten wire, polished and recrystallized to give large crystals, were measured and turned out to be 4.38 volts and 30 amp./cm^2 T^2, in agreement with the above theory.

[1] M. H. Nichols, Phys. Rev. **57**, 297 (1940).

156. The Contamination of Incandescent Molybdenum Filaments in a Vacuum Obtained by an Oil Diffusion Pump. FRANCIS T. WORRELL AND S. S. SIDHU, *University of Pittsburgh.*—Molybdenum filaments, heated to incandescence in a vacuum obtained by a diffusion pump using Octoil-S, were found to be contaminated by the oil when the vacuum was maintained at about 10^{-6} mm Hg. Microphotographs

of the contaminated filaments show roughened surfaces with deep, sharp-edged cracks such as might be expected of a contaminated surface layer of different expansivity than molybdenum. X-ray diffraction analyses of the contaminated filaments reveal the formation of (1) molybdenum carbide (Mo_2C), (2) solid solution of carbon in molybdenum, (3) graphite, and (4) an unknown substance.

157. New Absorption Bands in Colored Alkali-Halide Crystals. JULIUS P. MOLNAR, *Massachusetts Institute of Technology*.—The coloration produced by x-rays in crystals of the alkali-halides has been shown[1] to be due to a single absorption band which for most of the salts lies in the visible part of the spectrum. The absorption band is commonly attributed to the presence of color centers (sometimes referred to as Farb- or F-centers), the nature of which being not yet definitely established. A re-investigation of the absorption spectra of colored alkali-halide crystals indicates the presence of other weaker bands besides the main band. In the case of KCl, the new bands consist of three peaks on the long wave-length side of the main band. Their position and breadth depend on the temperature in a manner similar to that of the main band, indicating that their origin is probably due to trapped electrons and not colloidal particles. One of the new bands is of particular interest since it appears simultaneously with the main band in x-rayed crystals, and can be bleached. The other two bands appear only after long exposures and do not seem to bleach. The new absorption bands suggest the possibility of several trapping modes for free electrons in the alkali-halide lattices. Several trapping processes have been proposed in explanation of F centers, and it may be that more than one of these actually exist. Two of them seem especially likely processes, the trapping of electrons on cations[2] and in vacant holes left by missing anion.[3]

[1] E. Mollwo, Zeits. f. Physik **85**, 56 (1933).
[2] N. F. Mott, Proc. Phys. Soc. **49**, 32 (1937).
[3] A. von Hippel, J. Chem. Phys. **8**, 605 (1940).

158. Work Function and Double Layer. R. SMOLUCHOWSKI, *Princeton University*.—Work function is experimentally known to be different for different faces of a crystal. For tungsten the faces can be arranged according to decreasing work function as follows: 110, 211, 100, and 111. The differences are of the order of several tenths of a volt. The explanations suggested so far give either an incorrect sequence or a wrong order of magnitude for the observed differences. The author uses the theory of Wigner and Bardeen according to which the work function is a sum of a volume contribution and a double layer on the surface of the metal. The latter is due to the shift and rearrangement of the electron cloud on the surface. The calculation of the value of the double layer shows that it is strongly dependent on the orientation of the surface and gives the right order of magnitude of the differences of the work function for different faces. The sequence of the faces appears to depend mainly upon the type of crystal lattice and to a certain extent also upon the tendency exhibited by the electrons to form a smooth surface. Under reasonable assumptions the calculated sequence of the faces agrees with the experimental data for tungsten which were mentioned above.

Papers to be Read by Title

159. Equivalent Thickness of the Atmospheric Nitrous Oxide Layer. ARTHUR ADEL, *Lowell Observatory*.—The existence of a nitrous oxide layer in the earth's atmosphere was established by Adel in 1939.[1] The gas is presumably at a high level and of photochemical origin; and its infra-red bands appear to remain of nearly uniform strength throughout the seasons. The fine structure of the ν_1 band of atmospheric nitrous oxide at 7.78 mu has now been obtained with a 2400-line echelette grating ruled at the University of Michigan. The rotational structure is clearly distinguishable from the complex of atmospheric absorption upon which it is superimposed. From a comparison of the atmospheric absorption with the controlled absorption by nitrous oxide in the laboratory it appears that 3 mm of the gas (NTP) exercises as much absorption in ν_1 as does the atmospheric layer. However, since the infra-red absorption of N_2O is undoubtedly pressure sensitive this figure provides only a lower limit; for at the reduced pressures to which the layer is probably subject far more gas would be required to have the same effect. Nitrous oxide exercises both continuous and band absorption in the ultraviolet.[2]

[1] Arthur Adel, Astrophys. J. **88**, 186 (1938); **90**, 627 (1939).
[2] J. Nicolle and B. Vodar, Comptes rendus **210**, 142 (1940).

160. Phase Shifts in the Scattering of 100-Mev Protons by Protons. H. M. THAXTON AND S. H. MILES, *Agricultural and Technical College of North Carolina*.—The presence of s, p and d wave anomalies in the scattering of 100-Mev protons by protons has been investigated for the Gaussian potential well. The phase shift (K_0) due to the presence of an s wave anomaly is 24.5°; the phase shift (K_1) due to attractive p and repulsive p wave anomalies is 3.5° and 2.8°, respectively. The phase shift due to the d wave anomaly (K_2) is 1.5°. The calculations are performed by numerical integration of the wave equation and the subsequent adjunction of coulomb functions at $r=3e^2/mc^2$. These computations have been checked by the integral $\tan K_L = \int (V/E') F_L^2 d\rho$. The Coulomb functions used in these calculations are computed by series expansions and by integration of the differential equation,[1]

$$d^2u/d\rho^2 + (1/\log_{10} e)^2[\rho^2 + 2\eta\rho + (L+\tfrac{1}{2})^2]u = 0.$$

The series expansions converge only after thirty-five terms for Φ^* and thirty terms in Ψ are computed. For this energy the Mott ratio has been calculated for the scattering angle $\Theta = 30°$. The s wave anomaly gives a contribution of 79.5 percent to the scattering cross-section, the attractive p

anomaly a contribution of 21.9 percent and the d wave anomaly 3.6 percent. These results confirm the prediction[2] that the scattering cross section at high energies is influenced by the presence of p and d wave anomalies.

[1] E. R. Wicher, Terr. Mag. (Dec. 1936).
[2] H. M. Thaxton and L. E. Hoisington, Phys. Rev. **56**, 1194 (1939); G. Breit, H. M. Thaxton and L. E. Eisenbud, Phys. Rev. **55**, 1018 (1939).

161. Note on the Energy-Range Relations.* F. T. ROGERS, JR., *University of North Carolina.*—Let V_x be the energy of Mev. of an x-particle ($x=D$ or P for deuterons or protons) having a range of r_x cm in air at 760 mm Hg and 15°C. Let p_x represent r_x in all cases except for α-particles with ranges greater than 0.6, in which case let it be $r_\alpha-0.3$. Then the energy-range relations are approximated by

$$\log_{10} V_x = A_x + B_x \log_{10} p_x, \qquad (1)$$

and

$$\log_{10} p_x = C_x + D_x \log_{10} V_x; \qquad (2)$$

the constants A_x, B_x, C_x, and D_x are given in Table I, together with the average percent deviations (e) of these equations from the accepted relations.

TABLE I.

x	EQ.	DOMAIN	A_x, C_x	B_x, D_x	e
D	1	r_D: 0–12	−0.076	0.590	1
D	2	V_D: 0–3.6	0.129	1.695	2
P	1	r_P: 0–236	−0.170	0.567	1
P	2	V_D: 0–15	0.300	1.763	2
α	1	r_α: 0–0.6	0.391	1.453	4
α	2	V_α: 0–1.1	−0.269	0.688	3
α	1	r_α: 0.6–20.8	0.391	0.599	2
α	2	V_α: 1.1–15	−0.653	1.670	3

* This work was completed while the author was in residence at The University of Houston.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

National Academy of Sciences

Auditorium

SYMPOSIUM

OF

INVITED PAPERS

Introduction (Stellar Classification). G. GAMOW, *George Washington University.* 5 minutes

I. Energy Sources of Main Sequence Stars. H. BETHE, *Cornell University.* 25 minutes

II. Reactions of Light Elements in Red Giants. E. TELLER, *George Washington University.* 20 minutes

III. The Problem of White Dwarfs. R. MARSHAK, *University of Rochester,* AND C. L. CRITCHFIELD, *Princeton University and Institute for Advanced Study.* 30 minutes

IV. Stellar Explosions. G. GAMOW, *George Washington University.* 25 minutes

Author Index to Abstracts of Papers Presented at the Washington Meeting

Adel, **Arthur**—Nos. 7 and 159
Allis, **W. P.**—see Brown, Sanborn C.
Atwood, **H., Jr.**—see Colwell, R. C.

Bailey, **J. E.**—see Colwell, R. C.
Bainbridge, **K. T.**—see Sherr, R.
Banks, **Floyd R. and Park H. Miller, Jr.**—No. 153
Banning, **Mary**—No. 4
Bardeen, **J.**—No. 73
Barschall, **H. H., R. Ladenburg and C. C. Van Voorhis**—No. 18
Bearden, **J. A. and G. Schwarz**—No. 105
—— see Beeman, W. W.
Beardsley, **Niel F.**—No. 89
Beeman, **W. W. and J. A. Bearden**—No. 102
Beers, **Yardley**—No. 97
Beese, **N. C.**—No. 42
Bell, **M. E. and J. H. Findlay**—No. 45
Bennett, **F. D.**—see Ham, W. R.
Bergmann, **Peter G.**—No. 72
Beringer, **Robert and C. G. Montgomery**—No. 99
Bethe, **H. A.**—Nos. I and 136
Blewett, **John P. and Simon Ramo**—No. 43
Boeker, **G. F.**—see Reber, R. K.
Bohlke, **P. G., T. R. Cuykendall and H. S. Sack**—No. 134
Borst, **Lyle B.**—No. 141
—— see Newson, Henry W.
Bozorth, **R. M.**—see Williams, H. J.
Brooks, **Harvey**—No. 57
Brown, **Sanborn C. and W. P. Allis**—No. 95
Browne, **S. H. and C. T. Lane**—No. 129
Brunings, **J. H. M. and J. K. Knipp**—No. 29
Bueso-Sanllehí, **F.**—No. 48

Caldwell, **Wallace C.**—No. 135
Cleveland, **Forrest F. and M. J. Murray**—No. 52
Cole, **Kenneth S. and Robert H. Cole**—No. 113
Cole, **Robert H.**—see Cole, Kenneth S.
Collar, **H. W., J. M. Cork and G. P. Smith**—No. 120
Collins, **George B.**—see Feldmeier, J. R.
Coltman, **John W.**—No. 20
Colwell, **R. C., H. Atwood, Jr., J. E. Bailey and C. O. Marsh**—No. 112
Constant, **F. W. and R. E. Faries**—No. 125
Cork, **J. M.**—No. 104
—— see Collar, H. W.
Crenshaw, **C. M.**—see Manning, H. P.
Creutz, **Edward C. and Robert R. Wilson**—No. 14
—— see Wilson, Robert R.
Critchfield, **C. L.**—see Marshak, R.
Cuykendall, **T. R.**—see Bohlke, P. G.

Dawson, **L. H. and E. O. Hulburt**—No. 2
Dessauer, **G. and E. M. Hafner**—No. 139
Deutsch, **Martin**—No. 137
Dicke, **R. H. and John Marshall**—No. 17
Downing, **J. R. and A. Roberts**—No. 138
Dwyer, **Robert J.**—No. 76

Earle, **Marshall D.**—No. 148
Easley, **M. Adelaide**—see Forsythe, W. E.
Ellickson, **R. T. and B. Serin**—No. 44
Elliott, **D. R.**—No. 23
Evans, **Robley D. and Clark Goodman**—No. 33
—— see Goodman, Clark
—— see Kip, Arthur F.

Faires, **R. E.**—see Constant, F. W.
Feldmeier, **J. R. and George B. Collins**—No. 123
Findlay, **J. H.**—see Bell, M. E.
Forsythe, **W. E. and M. Adelaide Easley**—No. 39
Frevel, **Ludo K.**—No. 58
Furry, **W. H.**—No. 26

Gamertsfelder, **Carl**—No. 66
Gamow, **G.**—No. IV
Germer, **Lester H.**—see White, Addison H.
Good, **W. E. and G. Scharff-Goldhaber**—No. 19
Goodman, **Clark, Robley D. Evans and Patrick M. Hurley**—No. 34
—— see Evans, Robley D.
Green, **E. H.**—see Kurrelmeyer, B.
Green, **J. B.**—No. 10
Gunn, **Ross**—No. 80
Guth, **Eugene**—see Mullin, Charles J.

Hafner, **E. M.**—see Dessauer, G.
Ham, **W. R. and F. D. Bennett**—No. 131
Hansen, **W.**—No. 144
Hardy, **H. C. and W. H. Pielemeier**—No. 106
Harvey, **G. G. and L. J. Sullivan**—No. 78
Hawkes, **John B.**—No. 38
Haworth, **L. J.**—see Luebke, E. A.
Hazen, **Wayne E.**—No. 101
Hebb, **M. H. and H. Sponer**—No. 56
Heilprin, **Laurence B.**—No. 36
Hering, **K. W.**—see Warren, B. E.
Hoge, **Harold J.**—No. 37
Hubbard, **J. C.**—No. 109
Hughes, **Donald J. and Volney C. Wilson**—No. 90
Hulburt, **E. O.**—No. 1
—— see Dawson, L. H.
Humphreys, **Richard F. and Ernest Pollard**—No. 145
Huntington, **H. B.**—No. 149
Hurley, **Patrick M.**—see Goodman, Clark
Huxford, **W. S.**—see Jones, R. W.

Irvine, **John W.**—see Roberts, A.

Jacques, **R. B.**—No. 25
Jenkins, **F. A. and S. Mrozowski**—No. 8
Jensen, **Arthur S.**—No. 115
Jesse, **William P., E. O. Wollan and Marcel Schein**—No. 86
—— see Schein, Marcel
—— see Wollan, E. O.
Jones, **R. W. and Huxford, W. S.**—No. 98

Kendall, H. C.—see Overbeck, C. J.
Kerst, D. W.—No. 103
Kip, Arthur F. and Robley D. Evans—No. 32
Knipp, J. K.—see Brunings, J. H. M.
Koehler, J. S.—No. 150
Kratz, H. R. and J. E. Mack—No. 9
Kurbatov, J. D., M. L. Pool and H. B. Law—No. 27
—— see Law, H. B.
Kurrelmeyer, B., W. H. Mais and E. H. Green—No. 40

Ladenburg, R.—see Barschall, H. H.
Lamb, W. E., Jr. and A. Nordsieck—No. 69
Landé, Alfred—No. 70
Lane, C. T.—see Browne, S. H.
Lark-Horovitz, K. and W. A. Miller—No. 140
—— see Parshall, C. M.
Law, H. B., M. L. Pool, J. D. Kurbatov and L. L. Quill—No. 116
—— see Kurbatov, J. D.
Lawson, A. W.—No. 151
Livingston, M. Stanley—No. 24
Ludloff, H. F.—No. 133
Luebke, E. A., J. H. Manley and L. J. Haworth—No. 21

Mack, J. E.—see Kratz, H. R.
MacNair, D.—see Nix, F. C.
Mais, W. H.—see Kurrelmeyer, B.
Manley, J. H.—see Luebke, E. A.
Manning, H. P., C. M. Crenshaw and V. J. Young—No. 143
Margenau, H.—No. 74
Marsh, C. O.—see Colwell, R. C.
Marshak, R. E.—No. 124
—— **and C. L. Critchfield**—No. 111
Marshall, John—see Dicke, R. H.
Marton, L.—No. 77
Matheson, G. L.—see McAllister, E. D.
McAlister, E. D., G. L. Matheson and W. J. Sweeney—No. 41
McCreary, Ralph L.—No. 28
Metropolis, N.—No. 49
Miles, S. H.—see Thaxton, H. M.
Miller, Park H., Jr.—No. 147
—— see Banks, Floyd R.
Miller, W. A.—see Lark-Horovitz, K.
Millikan, R. A.—No. 85
Molnar, Julius P.—No. 157
Montgomery, C. G. and D. D. Montgomery—No. 96
—— see Beringer, Robert
Montgomery, D. D.—see Montgomery, C. G.
Mooney, Rose C. L.—No. 59
Morgan, F., M. Muskat and D. W. Reed—No. 110
Motz, Lloyd—No. 79
—— see Rothstein, Jacob
Mrozowski, S.—No. 47
—— see Jenkins, F. A.
Mulliken, Robert S.—No. 50
Mullin, Charles J. and Eugene Guth—No. 154
Murray, M. J.—see Cleveland, Forrest F.
Muskat, M.—see Morgan, F.

Neher, H. V. and W. H. Pickering—No. 83
—— see Pickering, W. H.
Newson, Henry W. and Lyle B. Borst—No. 142
Nichols, Myron H.—No. 155
Nix, F. C. and D. MacNair—No. 132
Nordheim, L. W.—No. 81
Nordsieck, A.—see Lamb, W. E., Jr.

Olsen, Leonard O.—No. 5
O'Neal, R. D.—No. 30
Overbeck, C. J. and H. C. Kendall—No. 108

Page, Chester H.—No. 35
Pardue, T. Eugene—see Shearin, Paul E.
Parshall, C. M. and K. Lark-Horovitz—No. 62
Pepinsky, R.—No. 61
Pickering, W. H. and H. V. Neher—No. 84
—— see Neher, H. V.
Pielemeier, W. H.—see Hardy, H. C.
—— see Telfair, D.
Platt, John R. and Ralph A. Sawyer—No. 12
Plesset, Ernst H.—No. 118
Pollard, Ernest—see Humphreys, Richard F.
—— see Smith, E.
Pool, M. L.—see Kurbatov, J. D.
—— see Law, H. B.
Present, R. D.—No. 22
Preston, W. M.—No. 3
Prigogine, J.—see Sack, H. S.

Quill, L. L.—see Law, H. B.

Ramo, Simon—see Blewett, John P.
Ramsey, W. E., W. F. G. Swann and Paul Weisz—No. 94
—— see Swann, W. F. G.
Rawcliffe, R. D.—No. 6
Reber, R. K. and G. F. Boeker—No. 126
Reed, D. W.—see Morgan, F.
Roberts, A. and John W. Irvine, Jr.—No. 117
—— see Downing, J. R.
Rogers, F. T., Jr.—No. 161
Rosen, N.—No. 71
Rossi, Bruno—No. 82
Rothstein, Jacob and Lloyd Motz—No. 13
Ruedy, J. E.—No. 65

Sack, H. S. and J. Prigogine—No. 55
—— see Bohlke, P. G.
Sakmann, B. W.—No. 111
Sawyer, Ralph A.—see Platt, John R.
—— see Wheatley, Marshall A.
Scharff-Goldhaber, G.—No. 119
—— see Good, W. E.
Schein, Marcel, William P. Jesse and E. O. Wollan—No. 87
—— see Jesse, William P.
—— see Wollan, E. O.
Schiff, L. I.—No. 68
Schwarz, G.—see Bearden, J. A.
Serin, B.—see Ellickson, R. T.
Shearin, Paul E. and T. Eugene Pardue—No. 100

Sherr, R. and K. T. Bainbridge—No. 122
Sidhu, S. S.—see Worrell, Francis T.
Smith, E. and Ernest Pollard—No. 146
Smith, G. P.—No. 121
—— see Collar, H. W.
Smith, Lincoln G.—No. 54
Smoluchowski, R.—No. 158
Sponer, H. and S. H. Wollman—No. 51
—— see Hebb, M. H.
Starr, C.—No. 127
Sullivan, L. J.—see Harvey, G. G.
Swann, W. F. G. and W. E. Ramsey—No. 92
—— see Ramsey, W. E.
Sweeney, W. J.—see McAlister, E. D.

Tatel, H.—No. 16
Telfair, D. and W. H. Pielemeier—No. 107
Teller, E.—No. 11
Thaxton, H. M. and S. H. Miles—No. 160
Turner, R. N.—see Wilson, V. C.

Van Vleck, J. H.—No. 128
Van Voorhis, C. C.—see Barschall, H. H.

Wait, G. R.—No. 114
Walerstein, I.—No. 53
Wall, C. N.—No. 67
Warren, B. E. and K. W. Hering—No. 60
Waterman, A. T.—No. 152
Weisz, Paul—No. 93
—— see Ramsey, W. E.
Welles, S. B.—No. 31
Wheatley, Marshall A. and Ralph A. Sawyer—No. 11
Wheeler, John A.—No. 75
White, Addison H. and Lester H. Germer—No. 64
Williams, H. J. and R. M. Bozorth—No. 130
Wilson, Robert R. and Edward C. Creutz—No. 15
—— see Creutz, Edward C.
Wilson, V. C. and R. N. Turner—No. 91
—— see Hughes, Donald J.
Wollan, E. O., Marcel Schein and William P. Jesse—No. 88
—— see Jesse, William P.
—— see Schein, Marcel
Wollman, S. H.—see Sponer, H.
Woods, L. H.—No. 46
Worrell, Francis T. and S. S. Sidhu—No. 156

Yearian, H. J.—No. 63
Young, V. J.—see Manning, H. P.